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COLORATION OF GLASS BY RADIATION

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PART I

Introduction

The coloration of a glass through the exposure to various kinds of radiation usually refers to the development of optical absorption bands, often very broad, in the visible region of the spectrum. The term discoloration is more commonly used in the glass literature for this particular effect to distinguish it from the coloration by ordinary means, such as the addition of coloring ions, atoms, atomic groupings, etc. In this paper, the terms coloration by radiations and discoloration are used as synonyms. Although a study of the absorptions in the ultraviolet and infrared regions are equally significant, the primary interest at the moment is in the visible part of the spectrum because of the fact that the discoloration of glass feared in optical instruments or desired in radiation dosimeters is usually detected by the eye.

There are so many kinds of primary and secondary atomic radiations that, on first thought, it may appear impossible to treat the effect of radiation on glass *in general*. However, as it will be demonstrated, common effects and consequences may be noted even when radiations of very different nature are encountered. This permits treating the subject with a certain generality.

The Nature of Various Radiations

Atomic radiations may include particles (obeying wave mechanical description), either neutral or charged (both positive and negative), with a mass from zero (such as that of a photon) to that of a large atom (such as fission fragments from uranium) and with energy from practically nil (such as a slow or "standing" neutron at a few degrees K.) to 10^{16} ev. (such as an energetic cosmic ray particle). There are photons (ultraviolet x-rays, γ-rays, etc.), neutrinos, negatrons (electrons) and positrons (from a few kev to hundreds or thousands of mev), mesons ($\pm$ μ mesons, $\pm$ and neutral π mesons, neutral ζ meson, $\pm$ and possibly neutral τ mesons, κ, χ and V particles of various energy mostly in mev ranges and higher), neutrons (from kev to hundreds or thousands of mev), and charged atomic nuclei from a few kev to hundreds or thousands of mev such as proton, deuteron, helium or carbon nuclei, fission fragments, etc. From a practical point of view, the radiations a glass scientist or technologist encounters most commonly are as follows:

(1) *Photons.* These include ultraviolet rays, x-rays, γ-rays, etc., with energy content determined by the familiar Planck expression: $h\nu$, where h is the Planck constant and ν the frequency of the electromagnetic vibration.

(2) *Electrons.* These can be either artificially accelerated or emitted from atomic nuclei. Positrons from nuclear disintegration should also be included. However, since they usually annihilate readily with an electron to yield two high energy photons, their effect on glass is similar to that of electrons and photons.

(3) *Slow Neutrons.* These are the neutrons in thermal equilibrium with general surroundings and are most abundant in and near a modern thermal nuclear reactor.

(4) *Fast Neutrons.* The intense sources of these neutrons (a few mev) are fission or fusion bombs, fast nuclear reactors, cyclotrons, or other nuclear machines. They give rise to charged fast moving nuclei upon collisions or nuclear interactions with stable atomic nuclei in matter.

(5) *Energetic Charged Particles.* These may be accelerated artificially in a nuclear machine or obtained through reactions such as that of slow or fast neutrons with matter. Protons, α-particles, and fission fragments are among the common ones. Many radioactive nuclei also emit α-particles upon disintegration.

Although one encounters neutrinos frequently, their extremely small interactions with matter render them relatively unimportant for our purpose. Mesons are very important from the viewpoint of modern nuclear researches, but are rather insignificant to the present study because of the extremely low intensity available today.

Among the common types of radiations mentioned above, high energy photons and neutrons are very penetrating. Low energy ones are usually selectively absorbed

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depending on the wavelength of the photons or neutrons and the nature of the material involved. Electrons are not as penetrating. Their ranges depend primarily on their energy. Common electrons or β-particles emitted from a radioactive nucleus, would be absorbed to a considerable amount by $\frac{1}{4}$" thickness of any solid material. For charged atomic particles, the stopping ranges are even smaller. The fission fragments from uranium or the α-particles from naturally radioactive nuclei can be stopped by a few centimeters of air or of any equivalent thickness of solid materials.

The Nature of Glass

Before discussing the effect of these common types of radiations on glass, it is essential to see what glass, in general, is.

Similar to other matter in the solid or liquid state, glass is made of two kinds of constituents: namely, the positively charged atomic nuclei and the negatively charged electrons. While the positions of the atomic nuclei are found rather permanently, though somewhat randomly located with respect to each other, the electrons may be thought of as moving rapidly and continuously, either surrounding a fixed nucleus and/or between two or more nuclei to form a stable system. The electrons moving around or between nuclei undoubtedly serve the role of a binding agent for the atomic nuclei. These electrons are capable of assuming a great many energy states. The transitions from one state to another occurs during the absorption of energy, a process that always accompanies the passage of radiations through the matter. The behavior of matter in general, or of glass in particular, is, therefore, a unique function of the positions of atomic nuclei and the energy states of the electrons. A parallel presentation of the picture is a chemical one in which matter in the solid or liquid state may be considered to be composed of alternative positive and negative atomic particles linked in three dimensions. The linkage is the direct result of the electronic bindings between these atoms and may be further differentiated for convenience as of the covalent or ionic type. Glass belongs to a group of substances in which the arrangement of the component atoms or ions in the linkage possess a permanence or degree of rigidity similar to that in the crystalline state and an orientation of atomic or ionic groupings quite random in nature similar to that characteristic of liquids. The degree of randomness, however, may not persist when one considers a size smaller than a few tens (or hundreds) angstroms (10^{-8} cm.) in linear dimension. It may be described as a solid of a randomly distorted crystalline lattice composed of essentially the same fundamental atomic groupings (for example, $(SiO_4)^{4-}$ units in a silica-glass), or equally well as a liquid in the modern sense* that has been frozen as such without much crystallization or regular orientation.

In general, both types of linkages exist in a common glass. The more covalent linkages, such as those between oxygen and the highly charged cations Si, B, P or Ge, serve in the formation of a network that underlies the backbone structure of the glass. The component which contributes to such strong net-work forming linkages is called a glass-former or a net-work former. The more ionic linkages, such as the typically ionic one between an oxygen and a sodium ion, are relatively weak and modify the structural nature of the glass. The component contributing to the more ionic linkage is called a modifier. Components which behave in between these two types are called intermediates. BeO is an example.

This summary description of the nature of glass omits the characteristics of its fine structures, but permits the discussion of the interactions of radiations with such an assembly of atomic nuclei and electrons in a simplified manner.

The Interaction of Specific Radiations with Glass

(1) *Interaction with photons or electromagnetic radiations.* The interaction of a photon, say below 1 mev, with glass may be largely attributed to the transfer of the photon energy, part by part, to electrons.

The direct interaction with nuclei is small, because of their relatively insignificant size (10^{-12} times the volume of that of the atom which is occupied by the electron cloud). The same is true for fast electrons and charged atomic particles. This does not mean that these radiations do not interact with the atomic nuclei, but rather that the probability of such interactions is small and that tremendous intensities are required before any noticeable mechanical or optical effects are observed due to direct nuclear interactions.

For photons below 1 mev, the interactions with electrons may be described by the Compton and photoelectric processes. The Compton process predominates at the higher energy side, in which the photon imparts part of its energy to an electron, thus setting it free from nuclear binding and imparting to it a considerable speed. The photon, in turn, loses energy and exhibits a shift towards longer wavelength. The process is repeated until most of the photon energy is transferred into the creation of cascades of free moving electrons of high speed. The photon energy may then reach the region in which the photoelectric process assumes larger cross-sections or sets in as the main process. In this latter process, the electron is set free from the atom or transferred to higher quantum states at the sacrifice of the total photon energy. Thus, the interaction of the photon with electrons in glass results in the production of free electrons of various speed or energy in cascade, and the excitation of bound electrons. High energy photons, that is those above 1 mev, may produce, in the Coulomb field of the nuclei besides effects of the types just mentioned, electron-positron pairs and disappear in the process. The behavior of the high energy electron thus produced will be discussed in the following section. The high energy positron produced at the same time will immediately annihilate with an electron found in the glass to form a pair of photons with energy generally lower than one-half that of the original pair-production photon. In this way the high energy photon is gradually degraded into fast moving electrons and photons of lower energy which in turn transfer their energy into cascades of free electrons and electrons in excited states.

(2) *Interaction with fast moving electrons.* Fast electrons, such as those from nuclear β-emission, from pair production, from the Compton process, or from artificial acceleration, ionize the atoms in glass. In other words, they also set electrons in glass free in motion or excite

*The modern concept of the liquid refers to the random structural arrangement of atoms or atomic groupings instead of to an ability of assuming the shape of the vessel containing it.

them to higher states. Photons may be produced at the same time. The process will repeat by itself until all fast moving electrons, including those from the second, third and later generations lose energy to the extent that they are no longer capable of setting free or exciting electrons in the glass. On the average, it takes about 32 ev. to set free an electron in the matter. It also takes energy to excite electrons to higher quantum states, although the amount of energy required is somewhat less. The net result of passing a fast electron through a glass is almost identical (except in range) to that of passing a high energy photon; namely, the production of free electrons and excitations of electrons to higher States. The electrons set free are said to be in the conduction band and their energies are considerably smaller than that of the initial electron which starts the whole process.

(3) *Interaction with charged atomic particles.* The charged atomic particles such as protons, deuterons, α-particles, fission fragments, etc., also cause production of free electrons (or ionization) and excitation of electronic states in glass. The power of interaction is much higher and the range of interaction is shorter. The particle spends much more energy per unit path length in glass than a photon or a fast electron. It is clear that the net result of passing a photon, an electron or a charged atomic particle is the same except the range of interaction is longest in the case of a photon and shortest in the case of a charged atomic particle. The intensity of interaction per unit length is weakest for the longest range and vice versa. In other words, the effect of a photon spreads out in a large region in a glass while that of a charged atomic particle concentrates in a very small region. The effect of the charged particle is, therefore, more severe in the affected region.

(4) *Interaction with neutrons.* The interaction is primarily a nuclear one because the interaction between electron and neutron is small, as was demonstrated in the experiments carried out by Rabi and Fermi. However, electronic effects similar to those described above result from secondary processes. The interactions may be classified according to the speed of neutrons:

(A) Slow neutrons. The intensity and the mode of interaction of slow neutrons vary widely not only with various elements but also with various species or isotopes belonging to the same element. Thus B^{10}, representing 18.4% of natural boron, and not B^{11} representing 81.6%, interacts strongly with a slow neutron to yield an energetic α-particle and a fast moving recoiling Li^{7} nucleus. Since boron is a common component in glass, this reaction is rather important. On the other hand, the interaction of a slow neutron with O^{16}, perhaps the most important component in a common glass, is very small. If the interaction does occur, a high energy photon or photons are emitted with the formation of a new stable nucleus O^{17} which recoils in the opposite direction to the emitted photon. Here the product formed is still oxygen, and as far as ordinary chemical properties are concerned, they are not changed. The element silicon, the most important element in a glass next to oxygen, has three isotopes, namely, Si^{28}, Si^{29} and Si^{30} with the relative natural abundances of 92.3, 4.7 and 3.0%. On the interaction with a slow neutron, Si^{28} and Si^{29} transform into stable Si^{29} and Si^{30} with the simultaneous emission of high energy photons, and Si^{30} transforms into radioactive Si^{31} and energetic photons. Si^{31} decays into a stable P^{31} with the emission of a β-particle which assumes a maximum energy of 1.8 mev and has a half life of 170 minutes. All the interactions of Si nuclei with slow neutrons are not as pronounced as that with B^{10}. The end results of the interaction may be summarized as follows:

(a) Atomic nuclei in the glass are transformed into other nuclei of the same or different elements.

(b) During the emission of the instantaneous photon or other nuclear particle upon the absorption of a slow neutron, the recoil of the nucleus causes itself and others in the path to be displaced from the original sites, thus creating lattice distortion and vacancies.

(c) The secondary nuclear particles formed, such as the instantaneous photons, α-particles, or β-particles, and photons from the radioactive nuclei created and also the recoiling nuclei, will all react with the electronic clouds in the manners described earlier to yield a large number of free and excited electrons.

(B) Fast Neutrons. The interaction of fast neutrons with any atomic nuclei known is not as high as that of slow neutrons with some nuclei such as B^{10}, Cd^{113}, etc. Consequently, the fast neutrons are quite penetrating in glass, as in other matter. The interaction may involve elastic or inelastic collisions which results in the transfer of kinetic energy with the creation of fast moving atomic nuclei. In general, for elastic collision, the lighter the nucleus, the higher is the transfer of the kinetic energy of the fast neutron. The fast neutrons may also react with a nucleus to form a new nucleus with the emission of other nuclear particles such as a proton, α-particle, etc. For example, S^{32} is converted into the radioactive P^{32} by a fast neutron with the instantaneous emission of a fast proton. It is obvious that the resulting effects of a fast neutron on glass are similar to that of a slow neutron and differ only in details such as in intensity of interaction, degree of penetration, energy of recoils, etc.

Basic Physico-Chemical Effects Arising From the Interaction of Radiations and Glass

It is possible to deduce from the above discussion that although the detailed descriptions of the interactions may depend upon the types and the energy contents of the radiations and upon the glass involved, generalizations can be drawn which are common to all. The basic physico-chemical effects of radiations on a glass are therefore summarized as follows:

(1) Creation of a large number of free moving electrons in glass, leading to two consequences:

(A) The escape of a free electron from a definite linkage causes an electron deficiency in the particular location. The physical process of depriving a location of electrons is the important chemical process called oxidation. The escape of electrons also causes a localized concentration of positive polarity which affect many physical properties of a glass.

(B) The free electrons, or the conducting electrons, contribute to new physical properties of a glass, such as photo-conductivity, etc. In addition, these electrons may settle down in any site that is electropositive in nature. Chemically, this constitutes the familiar reduction process. Also, a free electron may take residence in so-called negative ion vacancies that must be assumed to

exist in glasses as they do in crystals. A negative ion vacancy is a location where a negative ion such as oxygen is missing owing to impact of radiations, or other causes. As in crystals this "trapping" of an electron in a negative ion vacancy gives rise to an important "center" for spectral absorptions in or near the visible region which will be discussed in greater detail in the later sections.

(2) Excitation of electronic energy states. The important phenomenon of luminescence, among others, is the direct consequence of electronic excitation.

(3) Displacement of atomic nuclei and formation of vacancies. The displacement of atomic nuclei means the breaking of chemical bonds and the formation of new ones. It could also mean the total rupture or decomposition of the old chemical linkages and formation of new and possible weaker ones. This is certainly related to the mechanical and other properties of a glass and also to the creation of positive and negative sites or vacancies in the glass matrices, which is closely related to the formation of the color centers mentioned above. For intense radiation, the displacement actually causes the total mechanical rupture of the glass.

(4) Transformation of atomic nuclei into other nuclear species. This would mean the change of chemical compositions or introduction of impurities which may or may not be desirable. For example, the transformation of boron into lithium by the action of a slow neutron as discussed earlier may not be desirable for the glass structure in general. On the other hand, transformation of Si to P may not lead to harmful results.

In the above discussions, the formation of x-rays and ultraviolet radiations is not singled out for the reason that the effects of these radiations are directly connected with the formation of the free and excited electrons and vacancies which have already been taken into consideration.

This general picture is undoubtedly oversimplified, but should suffice in a first attempt to attack the problem of glass coloration by high energy radiations. It immediately follows that the well-known phenomena of solarization, luminescence and other photochemical effects of glass are closely associated or even identical with a certain phase of the effect of high energy radiations on glass. Since data and experiences on the latter are not yet abundant, those derived from solarization, luminescence and photochemical effects are of great value to the present study.

Intensity Ranges of Radiation Effects

From a practical point of view, the study of the effect of radiation of glass may be classified according to the intensity of radiations. The measurement of the intensity of various kinds of radiations is not an easy task. At present a radiological unit, called roentgen, or simply r, is generally adopted. The r unit is defined as that amount of radiation or radiations which will produce one electrostatic unit of charge in the form of ions, or 2.08×10^9 ion pairs, in 1 cm^3 of air at 0°C. and 760 mm pressure. It is obvious that this is no measure of the total energy of radiation, but rather of its absorptivity which differs with the types and energies of the radiations. For example, low energy photons or charged atomic particles give a higher yield of ionization per centimeter of path than high energy photons. In general, one r is equivalent to 83.8 ergs or 5.24×10^7 mev of energy released as ionization per gram of air. For the sake of general understanding, this is equivalent to the amount of energy that is emitted in one second from a radioactive 5 mev α-particle source of about 0.3 mc strength. One mc, or millicurie, is defined as that strength of radioactivity that decays at the rate of 3.700×10^7 disintegrations per second. The energy equivalent varies with types and energy ranges of radiations and also with the types of materials with which the radiation interacts. The above figures serve to give a general idea of the unit r.

The following classification which is based on the ranges of the radiation intensity is tentatively adopted for the study of coloration of glass by radiations:

(1) 600 r and below: Glasses sensitive to radiation dosage as low as 10 r have been devised by J. H. Schulman et al[147-149] and studied for industrial development in cooperation with the Bausch and Lomb Optical Company.[7] In practice, these glasses are useful as dosimeters since a single fatal dosage is reported[109] to be about 600 r or more. It will be interesting to see the greatest sensitivity that can be developed in a glass in order to detect very small amounts of radiation. This is particularly important since the accepted permissible dose rate in the United States is only 0.3 r per week. In the case of emergency, the tolerable dosage can be considerably higher.

(2) 600—10^{10} r. As radiation dosages increase, many glasses which are initially insensitive to radiations become colored. Monk's[116] pioneering study shows that many glasses become very darkly colored at about 10^6 r exposure. The saturation dosage for a pure SiO_2- glass is probably in the neighborhood of 10^8 r judging from the study of discoloration of pure vitreous and crystalline quartz by Forman.[68] Without knowing the actual limit of intensity of saturation dosage for a most coloration-resisting glass, we arbitrarily set it at 10^{10} r.

(3) Over 10^{10} r. At this range, the discoloration will reach saturation. In other words further exposure of radiations does not contribute further increase in coloration. However, as the radiation dosage is increased, the displacement and transformation of atomic nuclei in glass begin to be noticeably significant and cause rupture or mechanical cleavage of the glass. This field, though important, will not be considered at the present study because the glass will become darkly colored and non-transparent, thus useless for any optical purpose long before any mechanical damage sets in. It is clear that the present interest centers around the radiation dosages below 10^{10} r.

Phenomena Observed in Glass During Irradiation

We are now in position to view the various phenomena observed during the passage of radiations.

As mentioned earlier, the liberation of free electrons results in oxidation and reduction. The oxidation-reduction processes in glass have been long known to be associated with changes of color, particularly when ions capable of assuming two or more valencies are involved. The phenomenon is generally known as *solarization*. The reduction of some ions by the free electrons liberated by the radiation to metallic atoms constitute another

(*Continued on page* 546)

MEASUREMENT OF SURFACE TENSION OF GLASSES

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PART II

Correlation of Surface Tension with Composition

While any group of surface tension measurements on a series of glasses with varying compositions is in some measure a composition-surface tension correlation, several workers have attempted to systematize the subject.

Tillotson[33] attempted to assign empirical factors to various oxides from which the surface tension of a glass might be computed as follows:

$$\gamma = a_1p_2 + a_2p_2 + a_3p_3 + \ldots + a_np_n \qquad (29)$$

where:

p_i = percentage of component i.

a_i = empirical factor for component i.

He arrived at the following values of a_i for the indicated oxides: BaO, 195; B_2O_3, 45; CaO, 323; Na_2O, 160; SiO_2, 129. These factors do not agree with recent results, since, as stated in the section of this report on methods of measurement, his absolute surface tension values for the glasses from which the above factors were computed appear too low.

Badger, Parmelee and Williams[23] have added small, equimolar additions to twenty different oxides to a base soda-lime-silica glass and observed their effect on surface tension (Table III). Their conclusions are presented below.

(1) Zr and Ca increased surface tension 5%.
(2) Mn, Zn, Al, Co, Fe, Ni, Ca, Ba and Mg increased surface tension 3%.
(3) Si and Li increased surface tension 1%.
(4) Ti and Na decreased surface tension 1%.
(5) B and K decreased surface tension 3%.
(6) Pb decreased surface 10% and V 23%.

Babcock[16] found the increase in surface tension (at 1400°C.) due to the substitution of 0.1 mole fraction of one oxide for another. These data are given in Table XVIII.

Lyon[34] correlated the work of seven investigators to determine the effect of one per cent additions of various

TABLE I

Composition of glasses*
(Surface tension given on Table II)

No.	Na_2O (%)	CaO (%)	MgO (%)	SiO_2 (%)	Al_2O_3 (%)
S-0	16.02	7.77	3.02	73.18	0.0
S-2	15.71	7.62	2.97	71.74	1.96
S-4	15.41	7.48	2.90	70.37	3.83
S-8	14.84	7.20	2.80	67.75	7.41

*Computed from batch
Parmelee and Harman[25]

TABLE II

Summary of surface tension results.

Glass No.	Temperature (°C.)	Surface Tension (dynes/cm.)	Glass No.	Temperature (°C.)	Surface Tension (dynes/cm.)
S-0 series	1408	303.0	S-4 series	1350	323.4
	1408	304.0		1222	327.0
	1358	305.1		1248	325.5
	1330	305.5		1302	325.0
	1330	305.9		1390	324.5
	1288	307.0		1390	324.4
	1252	307.1		1302	324.7
	1226	308.8			
S-2 series	1387	317.3	S-8 series	1396	332.8
	1387	316.8		1396	331.0
	1327	317.6		1380	335.0
	1298	318.3		1328	338.0
	1298	318.3		1360	335.2
	1248	319.5		1312	336.5
				1281	337.2
				1220	339.1

Parmelee and Harman[25]

TABLE III

Surface tensions of a base glass (72.5% SiO_2, 17.4% Na_2O, 10.1% CaO) with equimolar additions of various oxides.

Glass No.	Additive Oxide (Wt. %)	Additive Oxide Formula	Surface Tension (dynes/cm) 1200°C.	1350°C.
1	None	—	304	302
5	1.3	Li_2O	306	305
6	2.7	Na_2O	300	298
7	4.1	K_2O	292	286
8	3.5	MgO	316	314
9	4.8	CaO	312	310
10	12.1	BaO	312	311
11	6.8	ZnO	315	312
12	3.1	B_2O_3	294	290
13	4.4	Al_2O_3	315	313
14	5.1	SiO_2	307	303
15	16.7	PbO	273	276
16	6.7	Fe_2O_3	314	311
17	6.3	CoO	314	313
18	6.3	NiO	313	311
19	6.6	Mn_2O_3	312	310
39	6.7	TiO_2	301	300
41	7.5	V_2O_5	235	236
42	10.0	ZrO_2	320	314
43	13.4	CeO_2	318	315
44	6.5	CaF_2	308	304
x12	2.7	B_2O_3	298	295
x19	9.1	Mn_2O_3	320	319

Badger, Parmelee, and Williams[23]

oxides on the surface tension of glasses in which the ratio SiO_2 : Na_2O exceed 3.25. His results are given in Table XIX. Lyon concludes that surface tension may be treated as an additive function of composition to within about four dynes per centimeter at 1200°C. and 1400°C.

At the present time research workers at the National Bureau of Standards (Shartsis and others[19,20,21,22]) are studying the surface tension of two component glasses. The results so far published in the *Journal of Research* for two component systems are given in Tables X, XI, XII, XIII and XIV.

TABLE IV

Surface tensions and compositions of some commercial glasses.

	A*	B**	C***	D	E	F	G
SiO_2	74.1	65.35	—	72.56	74.52	70.74	72.50
B_2O_3	—	—	0.70	1.00	—	—	—
PbO	—	17.50	—	—	—	—	—
Fe_2O_3	0.065	0.049	—	—	—	—	0.09
Al_2O_3	0.33	0.18	—	—	—	—	1.06
R_2O_3	—	—	—	3.58	0.45	0.33	—
CaO	4.65	0.21	—	4.02	4.35	13.72	9.24
MgO	3.23	0.03	—	2.54	3.18	0.12	3.00
P_2O_5	—	0.23	—	—	—	—	—
K_2O	0.04	8.40	—	—	—	—	—
Na_2O	16.65	5.70	—	—	—	13.11	13.59
Alkalis	—	—	—	16.30	16.51	—	—
SO_3	0.41	0.03	—	—	—	—	—
Na_2SO_4	—	—	—	—	—	0.85	0.41
As_2O_3	0.03	0.03	—	—	—	0.25	—
As_2O_5	0.07	0.36	—	—	—	—	—
NaCl	—	—	—	—	—	0.86	0.11
Cl	0.047	0.05	—	—	—	—	—
BaO	—	1.40	—	—	0.99	—	—
TiO_2	0.02	0.01	—	—	—	—	—
ZrO_2	0.003	0.005	—	—	—	—	—
MnO	0.003	0.088	—	—	—	—	—
Ignition Loss	0.30	0.32	—	—	—	—	—
Surface Tension at 1200°C. (dynes/cm.)	303	247	307	302	304	313	318
Surface Tension at 1350°C. (dynes/cm.)	302	245	299	299	300	314	315

*National Bureau of Standards glass No. 80
**National Bureau of Standards glass No. 89
***National Bureau of Standards glass No. 92
Badger, Parmelee, and Williams[23]

TABLE V

Surface tensions of some National Bureau of Standards glasses.

Glass	Temperature (°C.)	Surface Tension (dynes/cm)
N. B. S. No. 80	1488	302
" " " " "	1396	303
" " " " "	1277	304
N. B. S. No. 89	1289	242
" " " " "	1396	244
" " " " "	1500	244
" " " " "	1483	246*
N. B. S. No. 92	1500	303
" " " " "	1395	305
" " " " "	1288	306

*Obtained after heating 5 hours at 1500°C.
Bradley[24]

TABLE VI

Surface tensions of glasses with varying boric oxide — silica ratios.

Surface Tension (dynes/cm)	321.3	310.9	301.8	301.1	288.5	277.8
Batch Composition (Wt. %)						
SiO_2	76.0	74.4	72.9	70.9	68.4	65.9
B_2O_3		1.5	3.0	5.0	7.5	10.0
Na_2O	13.8	13.8	13.8	13.8	13.8	13.9
CaO	8.9	8.9	8.9	8.9	8.9	8.9
R_2O_3	1.35	1.35	1.35	1.35	1.35	1.35

Keppeler[12]

Temperature Coefficient of Surface Tension

If the surface tension of a glass composed of a single oxide is measured at increasing steps in temperature, the surface tension may be expected to decrease; in other words, the surface free energy decreases as the temperature is raised. This general tendency is also exhibited in most of the more complex glasses, the temperature coefficient of surface tension ($\Delta\gamma/\Delta t$), where $\Delta\gamma$ is the change in surface tension and Δt the change in temperature) usually being small (0.01 to 0.07 dynes/cm. °C.) and negative in sign.

In some glasses, especially those containing an oxide which greatly lowers the surface tension (A. A. Appen[35]), the temperature coefficient may become positive; that is, the surface tension may increase with increasing temperature. This phenomenon has also been shown by the work of Shartsis and Smock[19], Badger, Parmelee and Williams[23], and Bradley[36]. It is worthy of mention that each of the above investigators used a different method of surface tension measurement.

Shartsis and Canga[24] mention two theories as to the mechanism by which the surface tension may increase with increasing temperature. W. A. Weyl[37] postulated that a molecular group which is able to lower surface tension by becoming distorted easily at the surface layer will tend to become more symmetrical as the thermal agitation is increased. The distortion which accounted for the lower temperature low value of surface tension disappears at the higher temperature, and surface tension increases.

Worley[38] states that the increase in surface tension is due to an inward migration of the molecular species at the surface responsible for the original low value, this species becoming in some manner more soluble in the interior of the glass.

Freundlich[39] related the temperature coefficient of surface tension to the coefficient of cubical expansion as a constant ratio. Shartsis, Spinner and Smock[20] have shown evidence that such a ratio may exist for molten glass.

Published Data on the Surface Tension of Glass

The results of surface tension measurements obtained by early workers were not in close agreement with each other, and before about 1936 the values seemed to depend on the particular method of test. The following table illustrates the discordancy which existed. The glasses are predominantly soda-lime-silica.

TABLE VII

Composition of glasses, computed from batch (Surface tensions given in Table VIII)

Glass	Melt No.	Component oxides—weight per cent									
		SiO_2	PbO	BaO	B_2O_3	Na_2O	K_2O	ZnO	As_2O_3	Sb_2O_3	Other Oxides
F5725/42.2	5820	55.1	31.7	1.0	—	5.0	6.9	—	0.3	0.5	
F5795/40.9	6993	53.1	35.5	0.6	—	0.4	9.6	—	.3	—	
F605/37.9	4194	47.6	40.9	—	—	2.2	8.8	—	.5	—	
F617/36.6	6984	45.6	43.1	—	—	4.7	6.1	—	.5	—	
F620/36.2	6841	45.6	45.2	—	—	3.0	5.7	—	.5	—	
F649/33.8	6934	41.2	51.1	—	—	0.7	6.5	—	.5	—	
F666/32.4	6937	39.3	54.4	—	—	—	6.0	—	.3	—	
F6725/32.2	4316	38.8	55.4	—	—	—	5.5	—	.3	—	
F720/29.3	6860	34.1	62.4	—	—	—	3.2	—	.3	—	
F750/27.7	6397	31.2	66.2	—	—	—	2.3	—	.3	—	
BaC 541/59.8	6990	58.8	—	19.9	3.4	3.2	10.3	4.1	.3	—	
BaC 5725/57.4	6822	45.2	—	28.7	6.2	1.4	7.0	7.5	.3	.7	Al_2O_3 3.0
BaC 611/58.8	6680	38.3	0.2	42.8	10.7	—	—	—	.4	.2	Al_2O_3 2.9; CaO 4.5
BaC 617/55.0	6903	37.3	1.4	44.8	4.4	0.2	0.4	5.6	.3	.7	Al_2O_3 4.9
BaC 620/60.0	6495	37.2	—	41.6	11.0	—	—	—	.3	.2	BeO 4.2; CaO 3.5; ZrO 2.0
BaF 584/46.0	6494	49.8	18.8	13.4	—	1.6	8.2	7.8	.5	—	
BaF 588/53.4	4848	45.8	10.0	25.9	8.8	0.8	6.7	—	.5	—	ZrO_2 1.5
BaF 604/43.5	4411	45.7	23.3	13.6	—	—	8.9	8.1	.4	—	
BSC 511/63.5	6292	68.8	—	—	8.5	7.8	14.7	—	.2	—	
BSC 517/64.5	6929	66.4	—	—	12.4	8.2	12.0	0.5	.5	—	
BSC 536/64.5	6471	63.4	—	—	13.0	—	6.2	—	.4	—	BeO 2.0; SrO 10.0; Li_2O 5.0
LC 5125/60.5	6931	71.9	—	—	5.0	14.7	5.0	—	—	1.2	CaO 2.2
LC 5145/59.5	5767	71.2	—	—	5.0	14.7	5.0	—	—	1.2	CaO 2.9
LC 523/58.6	6910	70.2	—	—	1.5	14.0	2.5	—	—	1.2	CaO 9.4; Cl 0.7; SO_3 0.5
CF 5295/51.6	1280	65.1	10.0	0.2	—	11.6	6.1	5.0	.2	1.8	
NBS Standard Sample 80[a]	——	74.1	—	—	—	16.85	0.04	—	.10	—	CaO 4.65; MgO 3.23
NBS Standard Sample 80[a]	——	65.35	17.5	1.40	—	5.70	8.4	—	—	—	

Shartsis and Smock[19]. a—Standard Sample values are from chemical analyses.

Author	Date	Method	Order of Magnitude of Surface Tension (dynes/cm)
Tillotson	1911	Drop weight from filter	150
Griffith[40]	1920	Drop shape (Quincke)	430
Lecrenier	1924	Drop weight from crucible	450
Washburn and Shelton	1924	Dipping cylinder	150
Tammann and Rabe	1927	Elongated fiber	170
Keppeler	1937	Elongated fiber	160

More recent workers, however, have checked each others figures to within one per cent, using different methods. Among the procedures successfully used were the maximum bubble pressure, the modified dipping cylinder and the pendant drop. These values are in the order of 250 to 350 dynes per centimeter, depending upon the composition and temperature.

Included in the appendix are the results of several recent investigators. Tables I and II give the results of Parmelee and Harmon[25] who used the maximum bubble pressure method, as did Badger, Parmelee and Williams[23],

TABLE VIII

Surface tension of some optical glasses.

Glass	Observer			Surface tension (dynes/cm) 1300°C.	1200°C.	1100°C.	1000°C.	Reheating 1100°C.	1200°C.	1300°C.
F5725/42.2	2	....		230.5	228.7	226.7	225.0	227.1	229.2	231.1
	2	+		230.7	229.4	227.7	225.3	228.3	230.4	232.7
F5795/40.9	1	+		221.0	219.7	218.3	216.7	——	——	——
	2	....		221.7	219.4	218.8	217.7	——	——	——
F605/37.9	2	+		218.6	216.4	214.3	213.7	215.1	217.6	219.2
F617/36.6	1	+		222.8	220.6	218.9	216.5	218.7	220.9	223.3
	2	....		222.1	219.9	217.7	——	218.1	220.3	222.1
F620/36.2	2	+		221.5	219.0	217.1	215.7	——	——	——
	2	....		221.0	218.4	217.2	215.8	——	——	——
F649/33.8	1	+		216.0	214.1	212.0	212.6	——	——	——
	2	....		216.3	214.4	212.3	212.2	——	——	——
F666/32.4	1	+		216.4	214.7	212.8	212.9	214.6	——	——
	2	....		216.0	214.5	214.7	214.4	214.7	——	——
F6725/32.2	2	+		217.2	215.8	214.0	214.2	217.1	217.1	——
	2	....		216.0	214.3	214.2	214.5	215.5	216.0	——
F720/29.3	1	....		218.3	217.3	216.8	219.0	——	——	——
	2	....		218.6	218.4	218.0	217.8	——	——	——
F750/27.7	2	....		219.0	219.0	218.9	218.7	——	——	——
	2	....		218.4	218.6	219.6	219.3	——	——	——
BaC 541/59.8	2	....		263.8	264.7	265.0	265.4	——	——	——
BaC 5725/57.4	1	....		269.6	268.9	273.3	275.5	274.7	270.4	271.0
	2	....		271.4	270.6	270.8	275.0	272.0	——	273.3
BaC 611/58.8	1	+		288.4	288.0	287.0	287.3	288.3	288.8	——
	2	....		289.6	288.7	287.2	286.0	288.3	289.4	——
BaC 617/55.0	2	+		310.6	309.7	309.3	309.3	——	——	——
BaC 620/60.0	2	+		290.6	289.2	288.5	288.1	——	——	——
BaF 584/46.0	2	+		251.5	249.9	247.7	243.9	247.1	249.9	252.2
BaF 588/53.4	1	+		235.6	235.1	234.3	233.8	——	——	——
BaF	2	....		235.1	234.9	234.0	233.5	——	——	——
BaF 604/43.5	2	+		246.4	244.4	242.1	239.4	242.1	245.0	246.9
BSC 511/63.5	2	—		231.4	232.5	238.1	243.5	239.6	233.4	231.6
BSC 517/64.5	1	—		226.9	228.8	232.8	237.6	——	——	——
	2	....		227.7	229.3	232.3	237.2	——	——	——
BSC 536/64.5	2	+		245.2	244.5	244.9	244.6	245.6	245.2	246.1
LC 5125/60.5	2	—		251.6	254.4	262.1	——	——	——	——
LC 5145/59.5	2	—		251.7	254.4	261.7	——	——	254.8	252.3
LC 523/58.6	1	—		277.2	277.2	278.1	——	——	278.5	278.5
	2	....		276.9	277.3	278.0	——	——	278.1	277.9
CF 5295/51.6	2	....		249.2	249.7	250.2	——	250.8	250.0	249.6

Shartsis and Smock[39]

TABLE IX

Surface tension of compositions in the system. $PbO-B_2O_3$

PbO	Number of Tests	Surface tension (in dynes/cm) at— 600°C.	700°C.	800°C.	900°C.	1000°C.
Per cent						
0 ($100B_2O_3$)	2	——	——	75.9	79.5	83.0
4.9	1	——	——	75.5	78.2	——
10.1	1	——	——	75.5	78.4	——
16.6	2	——	——	74.5	78.2	82.1
21.6	2	——	——	76.1	79.4	——
27.8	2	——	——	76.3	80.1	——
31.4	2	——	——	75.5	80.1	——
34.4	2	——	——	75.4	78.5	——
39.9	2	——	——	75.4	79.1	——
44.9	4	——	——	84.8	89.3	——
47.0	1	——	——	90.6	93.3	——
49.1	2	——	——	89.4	91.6	——
51.3	2	——	——	104.0	103.0	——
56.3	1	——	——	121.8	116.4	——
60.9	1	——	——	136.8	129.8	——
66.4	2	——	159.8	150.6	144.2	——
70.7	2	172.3	165.2	157.7	152.9	——
75.5	2	——	166.0	162.6	160.3	——
80.0	2	167.6	165.7	164.3	163.0	——
82.0	2	163.6	163.0	162.3	162.0	——
84.1	2	161.6	162.2	162.4	162.8	——
86.0	2	159.0	160.0	161.6	162.2	——
88.1	2	156.8	159.1	160.6	162.2	——
89.8	2	156.5	155.7	158.4	160.4	——
91.1	1	151.5	152.7	155.4	157.4	——
94.0	1	——	——	——	151.0	153.1
96.0	1	——	——	——	144.5	146.2
97.9	1	——	——	——	132.3	139.3
100.0	1	——	——	——	132.0	134.8

Shartsis, Spinner, and Smock[20]

Tables III and IV. Certain of Bradley's work[36] are given in Table V, and Keppeler's[12] Table VI, both of whom also used the maximum bubble pressure method for the data included in this compilation. Tables VII through XIV are data from the recent National Bureau of Standards work (reference 19, 20, 21 and 22) performed by a modified dipping cylinder method. In Table XV the pendant drop results of Davis and Bartell[13] are given. Babcock[16] used a modified dipping cylinder method for the figures shown on Tables XVI, XVII and XVIII.

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TABLE X

Surface tension of compositions in the system. $PbO-SiO_2$

SiO_2	Number of Tests	Surface tension (in dynes/cm) at— 700°C.	800°C.	900°C.	1000°C.	1100°C.	1200°C.	1300°C.	1400°C.
Per cent									
3.20	1	——	——	134.4	142.0	145.4	154.2	158.0	161.3
5.17	1	——	——	147.8	157.7	152.1	158.0	164.1	162.7
9.36	1	——	——	173.6	176.5	179.2	182.0	183.3	——
13.18	2	——	——	183.7	186.5	189.6	193.9	197.3	——
15.30	2	——	187.3	192.4	194.6	196.1	——	——	——
16.76	3	——	——	——	199.4	202.2	205.7	210.2	——
17.50	2	193.2	196.8	199.1	201.6	204.4	208.2	209.4	——
24.30	3	——	——	217.1	219.1	221.0	222.6	223.4	——
27.12	3	——	——	224.5	225.6	225.7	226.5	227.2	——
28.31	3	——	——	——	227.8	228.4	227.5	228.5	——
30.08	3	——	——	——	231.3	232.0	232.7	230.5	229.1
30.16	2	——	——	——	230.0	230.8	230.8	231.7	232.2
32.74	3	——	——	——	233.7	235.0	235.6	234.5	235.1
34.91	2	——	——	——	233.0	233.7	234.0	235.0	235.7

Shartsis, Spinner, and Smock[20]

TABLE XI

Surface tensions of some compositions in the system ZnO-B_2O_3

Accepted Percentage of ZnO	Determination Number	Surface tension (dynes/cm) at—						
		1400°C.	1300°C.	1200°C.	1100°C.	1000°C.	900°C.	800°C.
0.0	—	97.2	93.6	90.1	86.5	83.0	79.5	75.9
10.0	1	——	95.2	91.1	86.5	82.0	78.4	——
50.0	1	——	——	90.9	——	——	——	——
50.0	2	——	——	——	87.9	83.2	79.7	——
55.0	1	——	153.8	143.6	137.4	138.2	——	——
55.0	*2	——	——	——	133.5	135.0	141.8	——
56.1	1	——	162.7	157.0	150.2	151.0	159.9	——
56.1	*2	——	——	——	144.2	147.9	156.5	——
58.6	1	——	184.4	181.8	179.4	180.0	185.2	(195.5)
58.6	2	——	185.8	180.2	177.9	178.9	183.5	(191.3)
58.6	*3	——	——	——	174.5	175.9	178.7	(189.5)
60.8	1	——	208.0	203.6	201.3	201.0	203.2	——
60.8	2	——	205.6	204.5	201.6	201.0	203.8	——
64.6	1	——	237.8	235.2	232.5	232.1	234.7	——
64.6	*2	——	——	236.6	234.1	234.5	235.4	——
65.6	1	——	250.0	246.6	244.2	242.0	(239.7)	——
65.6	2	——	250.5	245.8	243.8	242.5	——	——
70.6	1	——	286.8	285.2	281.5	277.0	——	——
70.6	2	——	287.1	285.7	283.4	280.3	——	——
70.6	3	——	289.7	286.5	283.4	278.7	——	——
74.6	1	——	321.6	318.9	314.7	——	——	——
74.6	2	——	321.8	319.3	315.6	——	——	——
79.5	1	355.3	355.9	360.3	——	——	——	——
79.5	2	353.3	354.2	——	——	——	——	——

*Not on regular temperature vs. time schedule.
Figures in parentheses are extrapolated values.
Shartsis and Canga[21]

TABLE XII

Surface tension, temperature coefficient of surface tension, and expansivity of liquids in the system Li_2O-SiO_2

Weight per cent of Li_2O	Mole per cent Li_2O	Surface tension at—					$\Delta\gamma/\Delta t$ at 1300°C.	Volume expansivity
		1400°C.	1300°C.	1200°C.	1100°C.	1000°C.		
		Dynes/cm	Dynes/cm	Dynes/cm	Dynes/cm	Dynes/cm	(Dynes/cm)/°C.	ppm/°C.
12.0	21.5	312.1	——	——	——	——	——	——
12.9	22.9	316.3	310.8	——	——	——	——	46.5
16.1	28.6	316.5	315.1	313.5	311.9	——	+0.015	60.7
17.8	30.3	316.8	316.7	316.2	314.7	312.8	+ .003	45.5
19.4	32.6	318.8	318.4	317.8	316.9	314.8	+ .005	76.8
20.0	33.4	320.1	320.2	320.0	319.4	——	0.	76.0
21.8	35.9	322.7	323.5	323.9	323.3	——	—0.006	87.7
23.9	38.7	327.9	328.4	329.1	328.3	——	— .006	81.3
25.9	41.3	331.1	332.1	333.1	334.1	——	— .010	97.2
27.8	43.6	332.2	334.2	336.3	338.4	——	— .020	91.8
29.7	45.9	337.1	340.8	343.4	——	——	— .032	103.9
31.9	48.5	{341.8 {341.0	344.5 343.9	348.1 346.9	——	——	— .032} — .030{	112.3
33.5	50.3	349.1	352.3	355.5	——	——	— .032	——
43.1	60.4	364.4	369.1[a]	373.9	——	——	— .048	——
46.9	64.0	370.0	374.9	379.1	——	——	— .046	——
49.3	66.2	373.6	a[381.3]	——	——	——	— .08	——

a—Figures in brackets are extrapolated values.
Shartsis and Spinner[22]

TABLE XIII

Surface tension, temperature coefficient of surface tension, and volume expansivity of some liquids in the system Na_2O-SiO_2

Weight per cent of Na_2O	Mole per cent of Na_2O	Surface tension at—						$\Delta\gamma/\Delta t$ at 1300°C.	Volume expansivity
		1400°C.	1300°C.	1200°C.	1100°C.	1000°C.	900°C.		
		Dynes/cm	Dynes/cm	Dynes/cm	Dynes/cm	Dynes/cm	Dynes/cm	(Dynes/cm)/°C.	ppm/°C.
20.0	19.5	273.1	274.6	275.6	276.2	276.6	——	—0.008	54
30.8	30.1	273.7	277.0	279.7	282.1	284.3	286.0	— .026	66
33.6	32.9	274.4	277.9	280.9	283.8	286.4	289.0	— .030	82
36.9	36.2	275.6	279.9	282.8	285.6	288.5	——	— .035	88
50.0	49.2	284.3	289.0	294.6	300.0	——	——	— .052	112

Shartsis and Spinner[22]

TABLE XIV

Surface tension, temperature coefficient of surface tension, and volume expansivity of some liquids in the system K_2O-SiO_2.

Weight per cent of K_2O	Mole per cent of K_2O	Determination number	Surface tension at—					$\Delta\gamma/\Delta t$ at 1300°C.	Volume expansivity
			1400°C.	1300°C.	1200°C.	1100°C.	1000°C.		
			Dynes/cm	Dynes/cm	Dynes/cm	Dynes/cm	Dynes/cm	(Dynes/cm)/°C.	ppm/°C.
13.6	33.0	1	207.7	212.1	216.1	221.1	223.0	—0.050	119.4
		2	204.7	209.5	214.6	219.6	——	— .046	——
		Avg	206.2	210.8	215.4	220.3	——	——	——
41.6	31.2	1	209.0	214.1	218.2	221.8	226.2	— .044	102.0
		2	207.3	211.8	216.1	220.5	224.8	— .045	——
		Avg	208.9	213.0	217.2	221.2	225.5	——	——
38.7	28.7	1	211.4	213.1	218.7	221.9	226.2	— .040	112.1
		2	208.7	212.8	216.6	220.7	224.6	— .038	——
		Avg	210.0	213.0	217.6	221.3	225.4	——	——
36.6	26.9	1	211.0	212.8	216.7	220.9	225.2	— .039	86.3
		2	209.3	213.2	217.1	221.4	225.3	— .034	——
		Avg	210.2	213.0	216.9	221.2	225.2	——	——
32.9	23.8	1	213.9	216.5	218.6	221.4	227.6	— .032	95.1
		2	213.4	216.1	219.8	222.6	226.2	— .028	——
		Avg	213.6	216.3	219.2	222.0	226.9	——	——
29.9	21.4	1	216.3	219.0	220.0	222.5	225.8	— .020	74.1
		2	216.6	218.5	220.5	224.1	227.4	— .019	——
		Avg	216.4	218.8	220.2	223.3	226.6	——	——
26.7	18.8	1	218.8	220.4	224.2	224.6	226.8	— .022	79.5
		2	218.2	220.2	222.6	225.0	227.6	— .024	——
		Avg	218.5	220.3	223.4	224.8	227.2	——	——
23.9	16.7	1	217.9	220.1	220.8	224.0	228.4	— .020	70.4
		2	219.9	222.0	223.9	225.5	——	— .018	——
		Avg	218.9	221.0	222.4	224.8	——	——	——

Shartsis and Spinner[22]

TABLE XV

Surface tensions of three different glasses.

Composition	A5	A6	A7	Composition	A5	A6	A7
SiO_2	72.4	71.5	71.5				
Na_2O	13.3	8.5	12.9	Surface Tension (dynes/cm)	334	312	344
K_2O		5.5					
CaO	9.2	13.5	12.0	Temperature °C. (approx.)	900	900	900
MgO	3.4	0.1	2.5				
Al_2O_3	1.1	0.2	0.2	Davis and Bartell[33]			

TABLE XVI

Chemical Analyses and Mol. Fraction Composition of Glasses (Surface tension given in Table XVII).

Glass No.		C-1	C-2	C-3	C-4	C-5	C-6	C-7	C-8	C-9	C-10	C-11	C-12
Percentage by weight composition	SiO_2	74.4	70.7	66.4	73.7	69.5	72.7	71.0	66.8	74.1	69.4	72.9	68.9
	Al_2O_3	0.2	0.2	0.1	0.2	0.2	0.3	4.2	4.2	4.1	4.2	4.1	4.2
	CaO	7.9	11.7	15.8	11.8	15.7	15.8	7.8	11.8	7.7	12.0	11.7	15.5
	MgO	0.2	0.1	0.2	0.1	0.2	0.2	0.1	0.1	0.2	0.2	0.2	0.3
	Na_2O	17.0	17.0	17.2	14.2	14.1	10.8	17.0	17.0	13.8	14.0	11.0	10.9
	SO_3	0.3	0.3	0.2	0.1	0.2	0.2	0.2	0.2	0.2	0.3	0.3	0.4
Mol. fraction composition	SiO_2	0.745	0.702	0.661	0.731	0.690	0.719	0.718	0.674	0.747	0.704	0.734	0.690
	Al_2O_3	0.001	0.001	0.001	0.001	0.001	0.001	0.025	0.025	0.025	0.025	0.025	0.025
	CaO, MgO	0.088	0.131	0.174	0.131	0.174	0.174	0.089	0.133	0.089	0.133	0.133	0.177
	Na_2O	0.166	0.165	0.164	0.136	0.135	0.106	0.168	0.168	0.139	0.138	0.108	0.108
Glass No.		D-1	D-2	D-3	D-4	D-5	D-6	D-7	D-8	D-9	D-10	D-11	D-12
Percentage by weight composition	SiO_2	73.4	67.4	75.1	69.3	77.6	71.0	69.8	63.6	70.8	65.3	73.9	67.5
	Al_2O_3	0.1	0.3	0.3	0.4	0.3	0.3	4.3	4.3	4.3	4.4	4.1	4.5
	CaO	6.1	9.5	5.8	9.4	5.9	9.8	5.8	9.6	6.0	9.6	5.9	9.6
	MgO	4.2	6.5	4.1	6.4	4.0	6.7	4.0	6.5	4.1	6.4	4.1	6.7
	Na_2O	15.8	15.8	13.9	13.9	12.1	12.2	15.6	15.6	14.1	14.0	11.8	11.6
	SO_3	0.2	0.4	0.4	0.4	0.1	0.1	0.4	0.4	0.4	0.4	0.1	0.1
Mol. fraction composition	SiO_2	0.723	0.654	0.742	0.673	0.760	0.692	0.694	0.625	0.714	0.644	0.734	0.664
	Al_2O_3	0.001	0.001	0.001	0.001	0.001	0.001	0.025	0.024	0.025	0.024	0.025	0.024
	CaO, MgO	.0123	0.194	0.123	0.194	0.123	0.194	0.125	0.197	0.125	0.197	0.125	0.197
	Na_2O	0.153	0.151	0.134	0.132	0.115	0.113	0.156	0.153	0.136	0.134	0.117	0.115

Babcock[16]

TABLE XVII

Experimental data for glass surface tension
(dynes per cm.)

Calcite

C-1		C-2		C-3		C-4		C-5		C-6	
°C.	S.T.*	°C.	S.T.*	°C.	S.T.*	°C.	S.T.*	°C.	S.T.*	°C.	S.T.*
1400	303	1395	312	1400	317	1400	316	1397	322	1400	325
1245	307	1302	315	1288	319	1325	315	1318	325	1306	326
1230	308	1216	316	1236	323	1238	318	1242	326	1248	328
1100	309	1140	317	1185	324	1168	317	1195	327	1232	330
				1120	321						

C-7		C-8		C-9		C-10		C-11		C-12	
1388	313	1393	323	1395	320	1392	327	1400	330	1402	332
1334	314	1292	325	1360	321	1319	327	1330	330	1370	332
1327	314	1244	325	1323	323	1248	329	1306	331	1330	333
1271	316	1177	327	1247	324	1217	330	1250	333	1291	333
1219	319									1234	336
										1231	336

Dolomite

D-1		D-2		D-3		D-4		D-5		D-6	
1387	309	1408	321	1397	316	1363	329	1406	322	1380	332
1317	310	1336	323	1339	317	1268	330	1370	323	1317	332
1304	311	1248	323	1288	318	1216	331	1270	324	1255	333
1275	311	1152	326	1195	320	1200	331	1255	327	1229	336
1208	313					1150	332			1185	338

D-7		D-8		D-9		D-10		D-11		D-12	
1393	319	1390	328	1395	325	1380	333	1400	328	1382	340
1334	321	1310	330	1329	326	1300	336	1380	328	1312	339
1277	322	1210	334	1260	328	1210	338	1348	329	1231	342
1213	324	1148	335	1215	328	1150	339	1294	330	1170	343

*S.T.—surface tension.
Babcock[16]

TABLE XVIII

Surface Tension Increase.

(At 1400°C. in dynes per cm. by substituting of 0.1 mol. fraction of one oxide for another)

Al_2O_3	for Na_2O	= 64.3
Al_2O_3	for SiO_2	= 42.0
MgO	for Na_2O	= 38.7
$CaO \cdot MgO$	for Na_2O	= 37.4
CaO	for Na_2O	= 36.1
Al_2O_3	for CaO	= 28.2
Al_2O_3	for $CaO \cdot MgO$	= 26.9
Al_2O_3	for MgO	= 25.6
SiO_2	for Na_2O	= 22.3
MgO	for SiO_2	= 16.4
$CaO \cdot MgO$	for SiO_2	= 15.1
CaO	for SiO_2	= 13.8
MgO	for CaO	= 2.6
MgO	for $CaO \cdot MgO$	= 1.3
$CaO \cdot MgO$	for CaO	= 1.3

Babcock[6]

TABLE XIX

Effect of 1% Oxide on the surface tension of glass in which the ratio $SiO_2 : Na_2O$ exceeds 3.25

Oxide	Surface Tension Increase (dynes/cm) 1200°C.	1400°C.
SiO_2	3.25	3.24
Fe_2O_3	(4.5)*	(4.4)
Al_2O_3	5.98	5.85
B_2O_3	0.23	0.23
CaO	4.92	4.92
MgO	5.77	5.49
BaO	(3.7)	(3.8)
Na_2O	1.27	1.12
K_2O	(0.00)	(—0.75)

*Values in parentheses are intended to be indicative of order of magnitude only; they are present in significant amounts in very few of the glasses treated.

K. C. Lyon[34]

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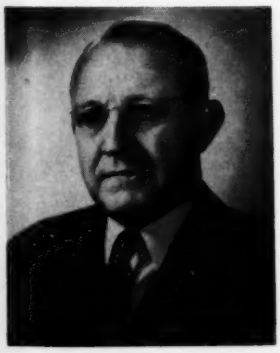
DR. R. R. SHIVELY MARKS 30 YEARS WITH DRAKENFELD COMPANY



Dr. R. R. Shively, noted as a pioneer in many of the modern technological developments in the glass and ceramic industries, this month marks his 30th anniversary with B. F. Drakenfeld & Co., Inc., New York.

Now Vice President of the company, Dr. Shively is presently in charge of Drakenfeld's newly expanded laboratories and plant at Washington, Pa. He has a long list of accomplishments in the glass and ceramic field dating back to 1913 when he developed a highly efficient illuminating glass which is still outstanding in its field. He was among the first to use selenium as a decolorizer and to make pink glass in a continuous tank.

Dr. Shively is believed to have made the first selenium amber produced in America and was a leader in the use of neodymium as a glass colorant. He also contributed to the technological knowledge required to produce cerium yellows in continuous tanks and when he joined Drakenfeld in 1922 as chief technologist, he inaugurated the policy of providing color research service for customers.

GCMI TO HOLD FALL MEETING

The Board of Trustees of the Glass Container Manufacturers Institute has scheduled the 1952 Fall Meeting at The Homestead, Hot Springs, Virginia, Monday, Tuesday and Wednesday, November 10, 11 and 12.

The purpose of the meetings will be to provide an opportunity for the Board, in compliance with Section 38 of the Code of Regulations, to receive semi-annual reports from the standing committees and to make the same available to the membership, and to hold the Semi-Annual Membership Meeting.

The following committee is in charge of the program for this meeting: Chairman J. M. Foster, J. P. Levis, F. B. Pollock and P. O'C. White.

PPG DONATES MULTIPLE FELLOWSHIP

The Pittsburgh Plate Glass Company will be the donor of a new multiple fellowship to be organized at Mellon Institute in Pittsburgh.

The research group, under the direction of Dr. T. H. Davies, will occupy itself with basic studies in areas of general interest to the company. Solid state physics and chemistry will be fields of investigation, as well as surface chemistry and the chemistry of molten inorganic systems.

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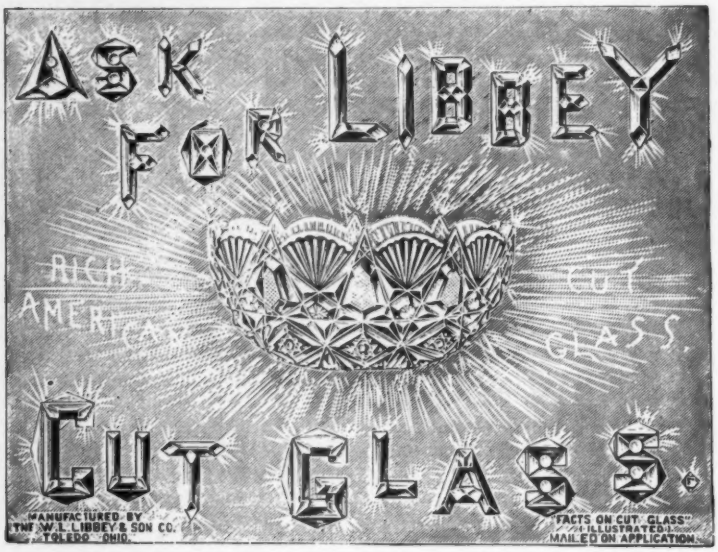

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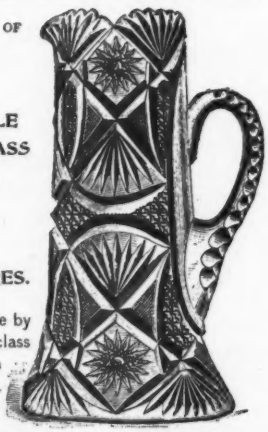

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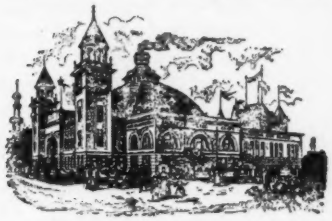

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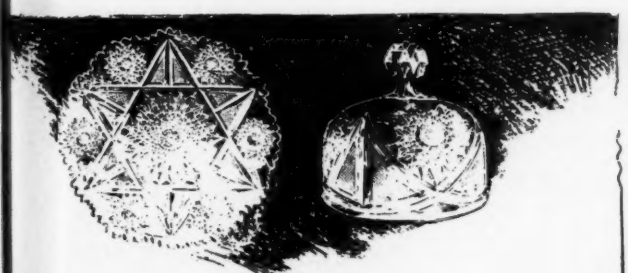

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Division of Ceramics, Pennsylvania State College, State College, Penna.

PART III

Editor's Note: Throughout this paper, the weight per cent composition of glasses determined by chemical analysis is marked by an asterisk; those not so marked represent the weight per cent composition of the oxide in the batch. If all the compositions investigated by a particular author have been chemically analyzed, the asterisk is placed near the first composition only and all the following compositions credited to that author also represent the weight per cent composition by chemical analysis of the glasses.

QUATERNARY SYSTEMS

System No.	System	Investigator	Weight Per Cent Composition				Coefficient of Expansion ($\alpha \times 10^7$)	Temperature Range (°C.)
34	Li_2O-Na_2O-CaO-SiO_2	S. C. Waterton & W. E. S. Turner, J. Soc. Glass Tech., *18*,268T (1934)	Li_2O	Na_2O	CaO	SiO_2		
			15	0	10	75	93.2	0-160
			13	2	10	75	93.5	
			11	4	10	75	92.9	
			9	6	10	75	92.6	
			6	9	10	75	89.1	
			4	11	10	75	88.0	
			2	13	10	75	88.1	
			0	15	10	75	83.0	
35	Li_2O-K_2O-CaO-SiO_2	S. C. Waterton & W. E. S. Turner, J. Soc. Glass Tech., *18*,268T (1934)	Li_2O	K_2O	CaO	SiO_2		
			15	0	10	75	93.2	0-170
			12	3	10	75	89.9	
			9	6	10	75	84.9	
			6	9	10	75	79.9	
			4	11	10	75	77.2	
			1.5	13.5	10	75	73.0	
			1	14	10	75	72.6	
			0	15	10	75	72.4	
36	Li_2O-B_2O_3-Al_2O_3-SiO_2	A. E. Dale, E. F. Pegg & J. E. Stanworth, J. Soc. Glass Tech., *35*,136T (1951)	Li_2O	B_2O_3	Al_2O_3	SiO_2		
			14.9	28.2	2.5	54.7	84	0-300
			14.8	26.2	4.9	54.1	79	
			14.5	22.4	9.7	53.4	79	
			14.3	18.8	14.3	52.6	81	
			14.1	15.3	18.8	51.7	82	
		L. Navias, J. Amer. Ceram. Soc., *18*,206 (1935)		6.7	19.0	7.5	66.8	50.7	
				7.0	18.0	5.0	70.0	50.7	25-100
37	Na_2O-K_2O-MgO-SiO_2	T. Kaneko, J. Japan Ceram. Assoc., *51*,487 (1943)	(1-x) Na_2OxK_2OMgO6SiO_2	Na_2O	K_2O	MgO	SiO_2		
			x = 0	18.1	—	11.7	70.2	79	100-300
			0.2	14.2	5.4	11.5	68.9	85	
			0.4	10.5	10.6	11.3	67.6	93	
			0.6	6.9	15.6	11.1	66.4	92	
			0.8	3.4	20.4	10.9	65.3	86	
			1.0	—	25.1	10.7	64.2	91	
			1·5Na_2O MgO·6SiO_2	24.9	—	10.8	64.3	122	
			Na_2O·O·5K_2O·MgO·6SiO_2	15.9	12.1	10.3	61.7	117	
			O·75Na_2O·O·75K_2O·MgO6SiO_2	11.7	17.8	10.1	60.4	116	
			1.5K_2O·MgO·6SiO_2	—	33.4	9.6	57.0	120.5	
			1·2Na_2O MgO·6SiO_2	20.9	—	11.3	67.8	83.0	
			O·6Na_2OO·6K_2O·MgO·6SiO_2	9.9	15.1	10.7	64.3	101	
			1·2K_2OMgO·6SiO_2	—	28.7	10.2	61.1	95.5	
			O·8Na_2OO·8K_2O·MgO6SiO_2	12.2	18.6	9.9	59.3	99	
38	Na_2O-K_2O-MgO-SiO_2	T. Kaneko, J. Japan Ceram. Assoc., *51*,487 (1943)	1Na_2O O·4K_2O 1MgO 6SiO_2	16.3	9.9	10.6	63.2	107	100-300
			O·7Na_2O O·7K_2O MgO 6SiO_2	11.1	16.9	10.3	61.7	108	
			ONa_2O 1·4K_2O MgO 6SiO_2	—	31.9	9.8	58.3	105	
39	Na_2O-K_2O-CaO-SiO_2	W. Hanlein, Zeitschr. techn. Physik, *14*,418 (1933) (Selected compositions taken from graphs)	Na_2O	K_2O	CaO	SiO_2		
			35	20	5	40	200	at 50
			30	25	5	40	200	
			25	30	5	40	200	
			35	10	5	50	175	
			30	15	5	50	175	
			17.5	35	5	52.5	175	
			33	5	5	57	150	
			22	15	5	58	150	
			25	5	5	65	125	
			15	15	5	65	125	
			5	25	5	65	125	

System No.	System	Investigator	Weight Per Cent Composition				Coefficient of Expansion ($\alpha \times 10^7$)	Temperature Range (°C.)
39 (*Continued*)			Na_2O	K_2O	CaO	SiO_2		
			17	5	5	73	100	
			10	12.5	5	72.5	100	
			5	17	5	73	100	
			10	5	5	80	75	
			5	10	5	80	75	
			—	15	5	80	75	
			33	5	10	52	150	
			15	25	10	50	150	
			10	30	10	50	150	
			15	15	10	60	125	
			10	20	10	60	125	
			15	6	10	69	100	
			7	15	10	68	100	
			8	5	10	77	75	
			4	10	10	76	75	
			30	7	15	48	150	
			25	12	15	48	150	
			15	25	15	45	150	
			24	5	15	56	125	
			15	15	15	55	125	
			7	25	15	53	125	
			15	5	15	65	100	
			10	11	15	64	100	
			5	17	15	63	100	
			20	20	20	40	150	
			10	32.5	20	37.5	150	
			20	8	20	52	125	
			15	14	20	51	125	
			10	21	20	49	125	
			13	5	20	62	100	
			10	9	20	61	100	
			5	16	20	59	100	
			5	5	20	70	75	
			20	8	25	47	125	
			15	14	25	46	125	
			10	21	25	44	125	
			10	8	25	57	100	
			5	14	25	56	100	
			2.5	2.5	25	70	75	
			10	5	30	55	100	
			7.5	10	30	52.5	100	
			5	14	30	51	100	
		T. Kaneko, J. Japan Ceram. Assoc., *51*,487 (1943)	(1-x) Na_2O x K_2O CaO 6SiO_2					
			x = 0.0	17.3	—	15.6	67.1	94	100-300
			0.2	13.6	5.1	15.3	66.0	102	
			0.4	10.0	10.1	15.1	64.8	101	
			0.5	8.2	12.6	15.0	64.2	105	
			0.6	6.6	14.9	14.8	63.7	103	
			0.8	3.2	19.6	14.6	62.6	99	
			1.0	—	24.1	14.4	61.5	98	
		W. S. C. Waterton & W. E. S. Turner J. Soc. Glass Tech., *18*,268T (1934)		*14.75	0	10.22	75.07	83.0	0-165
				12.94	1.94	9.98	75.07	82.0	
				11.06	4.12	9.87	75.02	80.3	
				8.97	6.11	10.03	75.04	81.0	
				5.98	9.00	10.00	74.97	80.8	
				4.13	11.17	10.07	74.86	78.0	
				1.85	13.14	10.13	75.15	72.7	
				0	14.95	10.04	74.92	72.4	
40	Na_2O-K_2O-BaO-SiO_2	T. Kaneko, J. Japan Ceram. Assoc., *51*,487 (1948)	(1-x) Na_2O x K_2O 1BaO 6SiO_2	Na_2O	K_2O	BaO	SiO_2		
			x = 0.0	13.6	—	33.6	52.8	108	100-300
			0.1	10.7	4.1	33.1	52.1	110	
			0.4	7.9	8.1	32.7	51.3	122	
			6.0	5.2	11.9	32.2	50.7	120	
			0.8	2.6	15.6	31.8	50.0	115	
			1.0	—	19.3	31.4	49.3	110	
41	Na_2O-MgO-CuO-SiO_2	M. D. Karkhanavala & F. A. Hummel J. Amer. Ceram. Soc., In print	Na_2O (1-x) MgO x CuO 5SiO_2	Na_2O	MgO	CuO	SiO_2		
			x = 0.0	15.4	10.0	—	74.6	69.6	20-150
			0.25	15.0	7.4	4.8	72.8	76.2	
			0.5	14.7	4.8	9.4	71.1	75.4	
			0.75	14.4	2.3	13.6	69.7	74.8	
			1.0	14.1	—	18.0	68.9	78.0	
42	Na_2O-MgO-CaO-SiO_2	T. Kaneko, J. Japan Ceram. Assoc., *51*,487 (1943)	Na_2O (1-x) MgO x CaO 6SiO_2	Na_2O	MgO	CaO	SiO_2		
			x = 0.0	18.1	11.7	—	70.2	79	100-300'
			0.3	17.8	8.1	4.8	69.3	92	
			0.5	17.7	5.8	7.9	68.6	96	
			0.8	17.4	2.3	12.6	67.7	97	
			1.0	17.3	—	15.6	67.1	94	

System No.	System	Investigator	Weight Per Cent Composition				Coefficient of Expansion ($\alpha \times 10^7$)	Temperature Range (°C.)
		Research Laboratory Owens-Illinois Glass Co.	Na_2O	MgO	CaO	SiO_2		
		(a) J. Amer. Cer. Soc.	13.9	4.9	7.1	73.6	87	80-170
		25,61 (1942)	13.9	6.4	9.4	69.3	91	
		(b) ibid., 25,401 (1942)	15.8	4.2	6.1	73.4	91	
		(c) ibid., 33,181 (1950)	18.0	4.2	6.0	71.3	99	
43	Na_2O-MgO-BaO-SiO_2	T. Kaneko, J. Japan Ceram. Assoc., 51,487 (1943)	Na_2O	MgO	BaO	SiO_2		
		Na_2O MgO $6SiO_2$	18.1	11.7	—	70.2	79	100-300
		Na_2O 0·6MgO 0·4BaO $6SiO_2$	16.0	6.2	15.8	62.0	94	
		Na_2O 0·5MgO 0·5BaO $6SiO_2$	15.5	5.1	19.2	60.2	97	
		Na_2O·BaO $6SiO_2$	13.6	—	33.6	52.8	108	
44	Na_2O-MgO-ZrO_2-SiO_2	V. Dimbleby, S. English, E. M. Firth, F. W. Hodkin & W. E. S. Turner J. Soc. Glass Tech., 11,52T (1927)	Na_2O	MgO	ZnO_2	SiO_2		
			*19.71	3.24	—	76.31	91.1	25-90
			20.00	2.56	2.24	74.58	91.0	
			21.04	1.76	3.35	72.98	90.3	
			20.42	6.68	—	72.77	93.9	
			18.50	4.96	1.83	72.42	87.1	
			18.40	3.46	3.74	73.15	86.3	
			19.11	1.83	5.95	72.36	84.9	
			18.82	0.23	8.01	71.34	84.8	
45	Na_2O-CaO-ZnO-SiO_2	A. R. Khan & H. E. Simpson Glass Ind., 31,407 (1950)	Na_2O	CaO	ZnO	SiO_2		
			16	9	0	75	82.6	90-310
			16	9	2	73	85.8	
			16	9	4	71	87.1	
			16	9	6	69	88.3	
			16	9	8	67	89.3	
			16	9	10	65	90.1	
			16	9	12	63	91.0	
			16	9	14	61	91.6	
			16	9	16	59	92.7	
			16	9	18	57	96.1	
			16	9	20	55	98.3	
46	Na_2O-CaO-Al_2O_3-SiO_2	S. English & W. E. S. Turner J. Soc. Glass Tech., 5,183T (1921)	Na_2O	CaO	Al_2O_3	SiO_2		
			*14.22	10.38	0.45	74.59	81.0	25-90
			13.54	9.47	2.67	74.13	73.6	
			13.72	7.91	5.23	74.25	70.0	
			13.54	7.10	7.10	73.98	68.8	
		W. B. Silverman J. Soc. Glass Tech., 24,59T (1940)	11	6	2	81	74	80-170
			13	6	2	79	81	
			15	6	2	77	88	
			17	6	2	75	96	
			11	8	2	79	74	
			13	8	2	77	82	
			15	8	2	75	90	
			17	8	2	73	97	
			11	10	2	77	77	
			13	10	2	75	84	
			15	10	2	73	91	
			17	10	2	71	99	
			11	12	2	75	79	
			13	12	2	73	86	
			15	12	2	71	94	
			17	12	2	69	101	
			11	14	2	73	81	
			13	14	2	71	88	
			15	14	2	69	97	
			17	14	2	67	103	
			11	6	4	79	74	
			13	6	4	77	81	
			15	6	4	75	88	
			17	6	4	73	99	
			11	8	4	77	74	
			13	8	4	75	82	
			15	8	4	73	89	
			17	8	4	71	96	
			11	10	4	75	76	
			13	10	4	73	83	
			15	10	4	71	90	
			17	10	4	69	99	
			11	12	4	73	79	
			13	12	4	71	86	
			15	12	4	69	93	
			17	12	4	67	101	
			11	14	4	71	82	
			13	14	4	69	90	
			15	14	4	67	97	
			17	14	4	65	104	
			11	6	6	77	75	

System No.	System	Investigator	Weight Per Cent Composition				Coefficient of Expansion ($\alpha \times 10^5$)	Temperature Range (°C.)
46 (*Continued*)			Na_2O	CaO	Al_2O_3	SiO_2		
			13	6	6	75	81	
			15	6	6	73	88	
			17	6	6	71	95	
			11	8	6	75	74	
			13	8	6	73	82	
			15	8	6	71	89	
			17	8	6	69	96	
			11	10	6	73	77	
			13	10	6	71	83	
			15	10	6	69	90	
			17	10	6	67	96	
			11	12	6	71	80	
			13	12	6	69	87	
			15	12	6	67	94	
			17	12	6	65	100	
			11	14	6	69	83	
			13	14	6	67	90	
			15	14	6	65	96	
			17	14	6	63	103	
			11	6	8	75	76	
			13	6	8	73	82	
			15	6	8	71	88	
			17	6	8	69	94	
			11	8	8	73	77	
			13	8	8	71	82	
			15	8	8	69	90	
			17	8	8	67	96	
			11	10	8	71	79	
			13	10	8	69	84	
			15	10	8	67	92	
			17	10	8	65	98	
			11	12	8	69	81	
			13	12	8	67	87	
			15	12	8	65	93	
			17	12	8	63	99	
			11	14	8	67	83	
			13	14	8	65	89	
			15	14	8	63	95	
			17	14	8	61	102	
47	Na_2O-CaO-MnO_2-SiO_2	A. A. Childs, V. Dimbleby, F. Winks & W. E. S. Turner, J. Soc. Glass Tech., *15*,172T (1931)	Na_2O	CaO	MnO_2	SiO_2		
			*16.60	10.11	—	72.28	91.5	0-130
			16.20	9.38	0.54	72.73	86.6	
			15.65	9.76	1.02	72.28	87.9	
			14.32	9.53	2.47	72.03	85.0	
			13.86	9.45	3.18	71.71	80.6	
			13.82	9.49	3.86	71.02	79.7	
			12.00	9.17	5.22	71.44	76.0	
48	Na_2O-CaO-CoO-SiO_2	W. E. S. Turner & F. Winks J. Soc. Glass Tech., *12*,57T (1928)	Na_2O	CaO	CoO	SiO_2		
			*16.86	8.14	—	74.52	90.2	0-100
			17.10	7.97	0.11	74.21	88.1	
			16.97	8.19	0.25	73.82	87.0	
			16.97	8.31	0.47	73.33	89.8	
49	Na_2O-SrO-PbO-SiO_2	M. D. Karkhanavala & F. A. Hummel J. Amer. Ceram. Soc., In print	$Na_2O(1-x)SrOxPbO05SiO_2$	Na_2O	SrO	PbO	SiO_2	
			x = 0.0	13.3	22.2	—	64.5	83.1	20-150
			0.25	12.5	15.7	11.3	60.5	80.1	
			0.5	11.8	9.8	21.2	57.2	77.4	
			0.75	11.2	4.7	30.0	54.1	75.9	
			1.0	10.6	—	38.0	51.4	77.8	
50	Na_2O-BaO-ZnO-SiO_2	T. Kaneko, J. Japan Ceram. Assoc., *51*,487 (1943)	$Na_2O(1-x)BaOxZnO6SiO_2$	Na_2O	BaO	ZnO	SiO_2		
			x = 0.0	13.6	33.6	—	52.8	108	100-300
			0.3	14.3	24.7	5.6	55.4	101	
			0.5	14.8	18.2	9.7	57.3	94	
			0.7	15.3	11.3	14.0	59.4	89	
			1.0	16.1	—	21.2	62.7	85	
51	Na_2O-BaO-PbO-SiO_2	T. Kaneko, J. Japan Ceram. Assoc., *51*,487 (1943)		Na_2O	BaO	PbO	SiO_2		
			Na_2O BaO $6SiO_2$	13.6	33.6	—	52.8	108	100-300
			Na_2O O·5BaO O·5PbO $6SiO_2$	12.6	15.6	22.7	49.1	107	
			Na_2O O·2BaO O·8PbO $6SiO_2$	12.1	6.0	34.9	47.0	100	
			Na_2O 1PbO $6SiO_2$	11.7	—	41.9	45.4	93	
52	Na_2O-PbO-ZnO-SiO_2	T. Kaneko, J. Japan Ceram. Assoc., *51*,487 (1943)	$Na_2O(1-x)PbO\ xZnO\ 6SiO_2$	Na_2O	PbO	ZnO	SiO_2		
			x = 0	11.7	41.9	—	45.4	93	100-300
			0.3	12.8	32.2	5.1	49.9	94	
			0.5	13.6	24.4	9.0	53.0	92	
			0.7	14.5	15.7	13.3	56.5	88	
			1.0	16.1	—	21.2	62.7	85	

System No.	System	Investigator	Weight Per Cent Composition				Coefficient of Expansion ($\alpha \times 10^7$)	Temperature Range (°C.)
			Na_2O	PbO	ZnO	SiO_2		
		C. W. Parmelee & R. G. Ehman J. Amer. Cer. Soc., *13*,475 (1930)	*15.4	21.7	4.9	57.6	89.1‡	32-110
			9.8	21.5	9.6	57.4	95.1	47-121
53	Na_2O-PbO-CdO-SiO_2	C. W. Parmelee & R. G. Ehman J. Amer. Cer. Soc., *13*,475 (1930)	Na_2O	PbO	CdO	SiO_2		
			*15.5	21.4	4.7	57.5	110.6‡	59-121
			9.5	21.8	9.7	57.6	75.0	32-124
54	Na_2O-FeO-Fe_2O_3-SiO_2	S. English, H. W. Howes, W. E. S. Turner & F. Winks, J. Soc. Glass Tech., *12*,31T (1928)	Na_2O	FeO	Fe_2O_3	SiO_2		
			*23.80	0.63	2.21	72.18	105.0	25-90
			21.36	0.84	4.84	71.33	99.0	
			22.36	1.05	6.52	69.02	99.9	
			17.38	1.05	9.95	70.00	86.2	
			17.20	1.89	10.16	69.24	83.3	
			15.34	1.78	15.42	66.63	83.9	20-130
			14.46	4.20	15.03	65.64	76.9	
			13.66	3.88	17.19	63.72	79.9	
			11.54	3.36	20.50	63.69	73.2	
			10.64	3.99	21.90	62.97	67.3	
55	K_2O-Rb_2O-CaO-SiO_2	S. C. Waterton & W. E. S. Turner, J. Soc. Glass Tech., *18*,268T (1934)	(K_2O & Rb_2O)		CaO	SiO_2		
			13	2	10.01	74.89	68.9	0 to 165
			10	5	10.08	75.13	66.1	175
			7	8	10.00	75.07	58.3	190
			4	11	10.14	74.87	56.5	185
			0	15	10.09	74.78	51.3	190
56	K_2O-PbO-CoO-SiO_2	W. E. S. Turner & F. Winks J. Soc. Glass Tech., *12*,57T (1928)	K_2O	PbO	CoO	SiO_2		
			*13.56	33.31	—	52.79	93.2	0-100
			13.64	33.08	0.11	52.77	93.1	
			13.51	32.83	0.20	53.09	93.8	
			13.76	31.47	0.53	53.83	92.4	
			13.49	32.20	0.90	53.29	90.4	
57	B_2O_3-Al_2O_3-SiO_2-P_2O_5	F. Drexler & W. Schutz Glastech. Ber., *24*,172 (1951)	B_2O_3	Al_2O_3	P_2O_5	SiO_2		
			22.2	33.4	22.2	22.2	60.5	
			17.7	33.3	23.5	23.5	38.3	
			12.5	37.5	25.0	25.0	35.8	
			26.67	40.0	26.7	26.7	32.3	
			26.4	31.6	21.0	21.0	39.2	
			3.4	41.4	27.6	27.6	28.8	

QUINARY SYSTEMS

58	Li_2O-Na_2O-B_2O_3-Al_2O_3-SiO_2	A. E. Dale, E. F. Pegg & J. E. Stanworth J. Soc. Glass Tech., *35*,136T (1951)	Li_2O	Na_2O	B_2O_3	Al_2O_3	SiO_2		
			—	26.0	19.4	8.4	46.2	115	0-300
			3.2	20.2	20.2	8.7	47.9	110	
			6.7	13.9	20.8	9.0	49.6	104	
			10.5	7.2	21.6	9.3	51.4	97	
		L. Navias, J. Amer. Ceram. Soc., *18*,206 (1935)	4.0	3.0	18.0	5.0	70.0	50.7	25-100
			4.0	3.0	13.0	5.0	75.0	49.3	
59	Li_2O-K_2O-B_2O_3-Al_2O_3-SiO_2	A. E. Dale, E. F. Pegg & J. E. Stanworth J. Soc. Glass Tech., *35*,136T (1951)	Li_2O	K_2O	B_2O_3	Al_2O_3	SiO_2		
			—	34.8	17.1	7.4	40.7	117	0-300
			2.9	27.8	18.2	7.9	43.4	108	
			6.3	19.7	19.4	8.4	46.2	100	
			10.1	10.6	20.8	9.0	49.5	91	
60	Li_2O-CaO-B_2O_3-Al_2O_3-SiO_2	A. E. Dale, E. F. Pegg & J. E. Stanworth J. Soc. Glass Tech., *35*,136T (1951)	Li_2O	CaO	B_2O_3	Al_2O_3	SiO_2		
			—	23.4	13.6	16.8	46.2	55	0-300
			3.4	18.0	14.0	17.2	47.5	61	
			6.7	12.4	14.4	17.7	48.8	67	
			10.3	6.3	14.9	18.3	50.2	72	
61	Li_2O-CaO-FeO-Fe_2O_3-SiO_2	K. Fuwa, J. Japan Ceram. Assoc., *46*,184 (1938)‡							

‡ Chemical analyses of the glasses reveal the presence of sufficient Al_2O_3 to consider these glasses as composed of six constituents.

62	Na_2O-K_2O-MgO-CaO-SiO_2	Research Laboratory Owens-Illinois Glass Co. J. Amer. Ceram. Soc., *33*,181 (1950)	Na_2O	K_2O	MgO_3	CaO	SiO_2		
			*18.0	—	4.2	6.0	71.3	99	80-170
			11.9	6.0	4.2	5.9	71.6	95	
			13.9	—	4.9	7.1	73.6	87	
			7.9	6.0	4.9	7.1	73.6	82	
			13.9	—	6.4	9.4	69.3	91	
			8.0	6.0	6.5	9.4	69.7	87	
63	Na_2O-K_2O-CaO-B_2O_3-SiO_2	W. E. S. Turner & F. Winks J. Soc. Glass Tech., *9*,389T (1925)	Na_2O	K_2O	CaO	B_2O_3	SiO_2		
			*6.86	7.90	8.56	—	75.82	80.2	25-90
			6.84	8.02	8.52	0.66	75.38	79.5	
			6.14	9.38	8.40	2.05	75.38	78.5	
			7.54	8.22	8.64	5.44	69.06	74.6	

‡ Values calculated from curves reproduced in Mr. Ehman's Thesis.

System No.	System	Investigator	Weight Per Cent Composition					Coefficient of Expansion ($\alpha \times 10^7$)	Temperature Range (°C.)
63	(*Continued*)		Na_2O	K_2O	CaO	B_2O_3	SiO_2		
			7.00	7.56	8.70	7.90	68.20	73.6	
			7.04	7.40	8.72	9.58	66.50	71.4	
			7.50	7.42	8.80	10.78	64.58	70.1	
			6.26	8.06	8.90	13.65	62.42	69.3	
			7.38	7.14	9.54	19.43	56.76	69.5	
			6.74	6.98	9.10	22.54	53.26	69.4	
			7.00	7.50	9.08	25.70	49.50	70.0	
			5.36	8.06	8.62	29.57	46.66	—	
			6.52	7.38	8.56	33.78	41.98	73.9	
			7.00	4.22	8.82	40.12	36.94	—	
64	Na_2O-MgO-CaO-BaO-SiO_2	Research Laboratory Owens-Illinois Glass Co. J. Amer. Ceram. Soc., *25*,61 (1942)	Na_2O	MgO	CaO	BaO	SiO_2		
			*13.7	4.9	7.1	1.0	72.7	87	80-170
			13.9	4.9	7.1	3.0	70.7	94	
			13.8	4.9	7.1	5.0	69.1	95	
			13.9	4.5	6.5	1.0	73.7	87	
			13.8	3.6	5.3	3.0	73.7	89	
			13.9	2.9	4.2	5.0	73.5	88	
			12.8	5.0	7.1	1.0	73.4	84	
			11.1	4.9	7.1	3.0	73.5	81	
			8.9	5.0	7.2	5.0	73.5	72	
65	Na_2O-MgO-CaO-ZnO-SiO_2	Research Laboratory Owens-Illinois Glass Co. J. Amer. Ceram. Soc., *25*,61 (1942)	Na_2O	MgO	CaO	ZnO	SiO_2		
			*13.8	4.9	7.0	1.1	72.6	87	80-170'
			13.8	4.9	7.1	3.3	70.4	88	
			13.8	4.9	7.1	5.4	68.2	90	
			13.9	4.5	6.5	1.2	73.5	86	
			13.9	3.8	5.3	3.3	73.4	87	
			13.9	2.9	4.1	5.4	73.2	89	
			12.9	4.9	7.1	1.2	73.6	85	
			10.9	4.9	7.1	3.3	73.5	80	
			9.0	4.9	7.1	5.4	73.3	71	
66	Na_2O-MgO-CaO-Fe_2O_3-SiO_2	Research Laboratory Owens-Illinois Glass Co. J. Amer. Ceram. Soc., *25*,401 (1942)	Na_2O	MgO	CaO	Fe_2O_3	SiO_2		
			*15.8	4.1	5.9	1.0	72.6	92	80-170
			18.8	4.1	5.9	2.9	70.7	94	
			15.9	4.2	5.9	4.9	68.6	94	
			15.9	2.7	5.3	1.0	73.6	92	
			15.9	2.9	4.1	2.9	73.6	92	
			15.9	2.1	2.9	4.9	73.6	91	
			14.9	4.1	6.0	1.0	73.5	88	
			13.0	4.2	5.9	3.0	73.5	83	
			11.1	4.1	5.9	4.8	73.6	76	
			13.9	4.9	7.1	—	73.6	87	
			13.9	4.9	7.0	1.0	72.6	87	
			14.0	4.9	7.1	2.9	70.5	89	
			14.0	5.0	7.1	5.0	68.6	88	
			13.9	4.5	6.6	1.0	73.5	88	
			13.9	3.7	5.4	3.0	73.6	86	
			14.0	2.9	4.2	5.0	73.6	88	
			13.0	5.0	7.1	1.0	73.5	83	
			11.0	5.0	7.2	3.0	73.6	79	
			9.0	5.0	7.1	5.0	73.7	73	
67	Na_2O-CaO-FeO-Fe_2O_3-SiO_2	K. Fuwa, J. Japan Ceram. Assoc., *46*,184 (1938)‡							
68	K_2O-CaO-FeO-Fe_2O_3-SiO_2	K. Fuwa, J. Japan Ceram. Assoc., *46*,184 (1938)‡							

‡Chemical analyses of the glasses reveal the presence of sufficient Al_2O_3 to consider these glasses as composed of six constituents.

69	MgO-CaO-BaO-Al_2O_3-SiO_2	J. E. Stanworth J. Soc. Glass Tech., *30*,381T (1946)	MgO	CaO	BaO	Al_2O_3	SiO_2		
			4	12	8	24	52	50.1	0-400
			4	10	8	24	54	45.7	
			4	8	8	24	56	44.2	
			4	6	8	24	58	40.4	
			12	8	—	24	56	44.4	
			10	4	8	24	54	44.7	
			8	4	8	24	56	40.2	
			6	4	8	24	58	39.6	
			4	8	8	24	56	44.2	
			8	8	4	24	56	43.3	
70	Na_2O-B_2O_3-Al_2O_3-SiO_2-P_2O_5	F. Drexler & W. Schutz Glastech. Ber., *24*,172 (1951)	Na_2O	B_2O_3	Al_2O_3	SiO_2	P_2O_5		
			—	10	30	40	20	38.1	
			5	10	45	20	20	—	
			10	10	40	20	20	92.6	
			15	10	35	20	20	112.6	
			5	10	30	35	20	53.3	
			10	10	30	30	20	103.6	
			15	10	30	25	20	124.5	
			20	10	30	20	20	119.3	

(*Continued on page* 550)

FERRO CORPORATION STARTS FIBER GLASS PRODUCTION

According to W. G. Cole, Jr., Manager of the Fiber Glass Division of the Ferro Corporation, on June 14th the first shipment of Ferro Fiber Glass was made. The first material produced was in the form of "roving" which is a thirty-five pound ball of continuous strand fiber glass widely used for the reinforcement of plastics as well as for other industrial purposes.

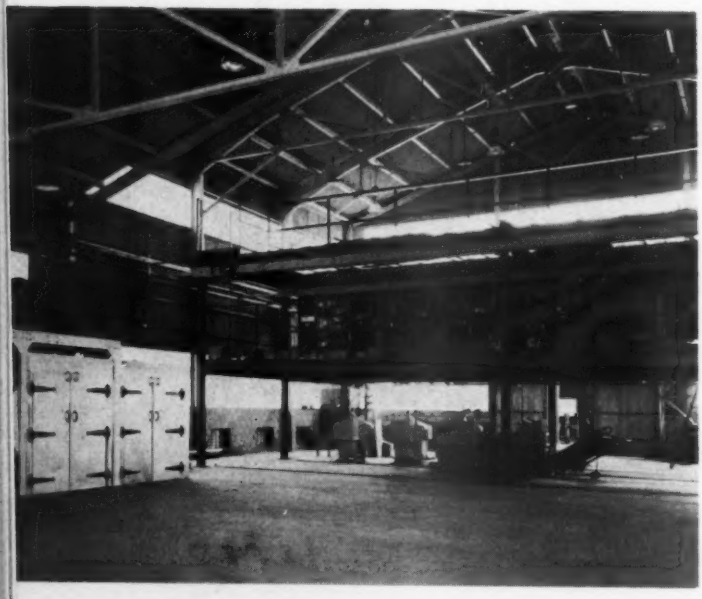
W. G. Cole, Jr.

This shipment represents the culmination of eleven months effort and the involvement of almost a million dollars in capital from the time at which Ferro accepted a license to manufacture Fiber Glass under the patents of Owens-Corning Glass Corporation.

Ferro plans to specialize in the supply of fiber glass to plastic reinforcement users and the various products to be marketed will all be designed for this trade. These products are roving, chopped strand, and various weights and treatments of bonded chopped strand will enable Ferro to offer the best possible service to this industry.

The initial output of the factory will be rather modest but present plans call for quadrupling production within the next year's time.

Ferro's prime business is the manufacture of glass in the form of porcelain enamel. Thus, while fiber glass represents a new form and new production methods, the basic art does not differ widely from a field in which the company has had thirty years of experience and has become one of the world's largest suppliers. They firmly believe that their knowledge of glass formation and glass-making techniques will, in time, make important contributions in the fiber glass field.



Dr. G. H. McIntyre, Ferro's Vice President in Charge of Research, has had a sizable research program under way for some time in the Central Research Laboratories. This program holds promise for interesting improvements in fiber glass products and it is expected that the fruition of this work will bring wider fields of application within the scope of plastic manufacturers who use fiber glass reinforcements.

With the exception of a few innovations in process, Ferro will manufacture its continuous strand by the established marble method in which the continuous strands are mechanically attenuated from marble melts. The bonded chopped strand mat, however, will be produced on a completely new machine which was designed by Ferro engineers after extensive experiments in the laying up of uniform jackstraw patterns in bonded mats. This mat machine will be in operation in a very short while and it is expected that highly uniform quality mats will be available from it.

The mat production unit incorporates flexible features which will enable Ferro to supply a great many of the specialized requirements of laminators using reinforcement mats. The machine allows for the use of a wide range of binder compositions which will produce fifty-inch wide mat in continuous lengths which will be compatible with a wide range of laminating resins.

For industrial concerns who are not in the plastic business but who have parts or products which offer the possibility of using fiber glass as a reinforcement in plastics, Ferro will offer a new service called "Fibercating." This service offers to potential users the facilities of a small but completely modern plant in which production trials and limited production runs can be undertaken for parts of almost any size and shape.

The "Fibercating" service offers the complete designing of the part for use in fiber glass reinforced plastic, the fabrication of molds, production trials and production runs on new items.

FOSTORIA OPENS NEW YORK CITY DISPLAY ROOM

The Fostoria Glass Company, Moundsville, West Virginia, has opened a new display room at 225 Fifth Avenue in New York City. The entire space was designed and decorated by Harper Richards, Chicago interior designer and architect.

In the display of glassware, both fluorescent tubes and incandescent bulbs are used, a technique for combining the two types of lighting so that a minimum of lighting units are used. The background colors and materials are varied. In one section opaque white glass with fluorescent lighting from the back has been used. This has proved very effective for the display of plain and colored glassware.

Inventions and Inventors

Annealing and Tempering

Tempering Glass. Fig. 1. Patent No. 2,608,029. Filed June 24, 1947. Issued Aug. 26, 1952. One sheet of drawings. Assigned to Blue Ridge Glass Corporation by Theodore W. Glynn.

An apparatus for tempering curved sheets of glass is described. Provision is made for preventing the distortion or flattening of the curved sheet during heating by supporting the sheet on serrated metal edges 5a.

Located centrally below the rest 5 and outside of the heating furnace is the blast trunk 6 having nozzles 6a projecting radially from one segment thereof at intervals along its length. The blast trunk may be oscillated around its axis by handle 6b. Provision for blasting above is made by means of the curved hood 7 having downwardly projecting blast nozzles 7a.

The heating furnace is of improved construction and not shown in the drawing.

The patent contains two claims and the references cited were: 1,454,200, Wells et al., May 8, 1923; 1,809,534, Tillyer et al., June 9, 1931; 2,376,872, Harris, May 29, 1945; 2,409,284, Jackson, Oct. 15, 1946; 393,491, Great Britain, June 8, 1933; and 829,655, France, June 4, 1938.

Molds for Bending Glass. Fig. 2. Patent No. 2,608,030. Filed Oct. 9, 1947. Issued Aug. 26, 1952. Three sheets of drawings. Assigned to Libbey-Owens-Ford Glass Company by Joseph E. Jendrisak.

An improved mold for bending is shown in perspective view in Fig. 2. The frame 1 having a shaping surface 2 that conforms to the marginal area of the sheet of glass 3 is made of stainless steel. The base members 4, 5, 6 and 7 and uprights 8 and 9 are also made of stainless steel tubing welded together at the corners and hold frame 1 in an inclined position. The frame 1 is placed in an inclined position to locate the portion of the glass to be bent in the higher and hotter parts of the furnace while keeping the straight part of the glass in a cooler region. The particular shape shown consists of a relatively sharp curve. Many other molds and shapes are described and the drawings must be seen to be thoroughly understood.

The patent contains 11 claims and the references cited were: 417,097, Scott, Dec. 10, 1889; 682,570, Sage, Sept. 10, 1901; 2,003,383, Miller, June 4, 1935; 2,190,807, Steinberger, Feb. 20, 1940; and 2,297,315, Owen, Sept. 29, 1942.

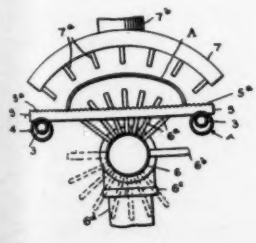


Fig. 1. Tempering Glass.

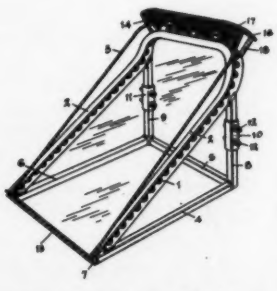


Fig. 2. Molds for Bending Glass.

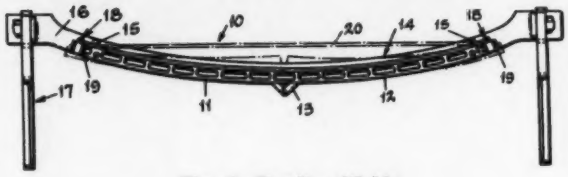


Fig. 3. Bending Mold.

Bending Mold. Fig. 3. Patent No. 2,608,799. Filed Sept. 22, 1949. Issued Sept. 2, 1952. One sheet of drawings. Assigned to Libbey-Owens-Ford Glass Company by Eugene W. Babcock.

Present-day continuous production of bent glass sheets requires improved molds with special equipment which eliminates the need for selective fitting of the glass. The provision of sheet positioning permits an unbent glass sheet to be quickly and accurately mounted in bending position on the mold.

Fig. 3 shows a shallow bend mold 10 of hinged construction. The mold members 11 and 12 are pivotally suspended in the corner areas of the U-shapes by means of a plurality of links 15. Special locating devices 18 are mounted on the cross web 19 of each mold member 11 and 12 for facilitating accurate loading. The accuracy of bending contours is also improved by the use of contact helical coils (not shown) on the edge of the molds.

The patent contains 8 claims and the references cited were: 1,999,558, Black, Apr. 30, 1935; and 2,429,692, Joyce, Oct. 28, 1947.

Feeding and Forming

Glassware Forming Machine. Fig. 4. Patent No. 2,607,166. Filed Nov. 23, 1946. Issued Aug. 19, 1952. Five sheets of drawings. Assigned one-half to Henry C. Daubenspeck and one-half to Samuel E. Winder by Harold A. Youkers.

This invention relates to a complicated mechanism by which a glass forming machine and a glass feeder may be operated concurrently from a power shaft. The mechanism also automatically causes the feeder to continue to operate from another power shaft without operation of the forming machine, whenever the latter is stopped. The apparatus provides great flexibility of operation and at the same time rugged and durable equipment.

Fig. 4 is a plan view showing the disposition of the several elements of the mechanism in combination with parts of a glassware molding machine and feeder shown diagrammatically.

The patent contains no claims and the references cited were: 1,692,589, Soubier, Nov. 20, 1928; 1,996,579, Johnstone et al., Apr. 2, 1933; 2,026,023, Du Bois, Dec. 31, 1935; 2,167,676, Pechy, Aug. 1, 1939; 2,224,767, Du Bois, Dec. 10, 1940; 2,330,985, Meyer, Oct. 5, 1943; and 2,384,498, Sloan, Sept. 11, 1945.

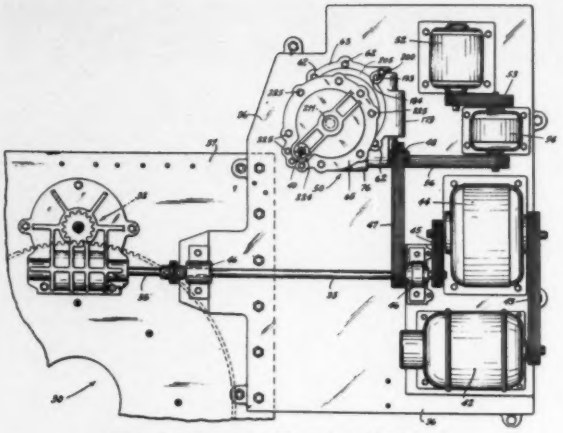


Fig. 4. Glassware Forming Machine.

Glass Feeder. Fig. 5. Patent No. 2,607,170. Filed June 15, 1950. Issued Aug. 19, 1952. One sheet of drawings. Assigned to Owens-Corning Fiberglas Corporation by Ralph DeVries.

A metallic feeder is provided which converts the flow of glass into a plurality of small streams. The apparatus contains no expensive noble metals, but consists of approximately 15% to 35% chromium, 0.25% to 2% silicon, and 63% to 84.75% nickel.

The drawing shows a container 10 which is connected to feeder 11. The feeder itself may take the form of a four-walled container having side walls 21 and a bottom wall 22 secured to the walls by a welding having the same composition as the alloy. The plate 22 has a plurality of openings from which the glass streams 12 issue. Each opening is a hollow core of a cylindrical nipple 23.

The alloy is relatively inexpensive, chemically stable in contact with glass up to 2000°F., dimensionally stable and non-volatile at the above temperature and can be cast, forged or machined.

The patent contains three claims and references cited were: 1,190,652, Henderson, July 11, 1916; 2,238,160,

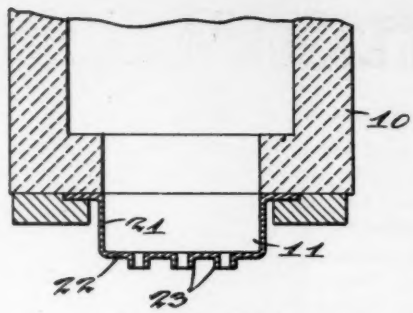


Fig. 5. Glass Feeder.

Doom, Apr. 15, 1941; 293,727, Great Britain, July 9, 1928; 355,083, Great Britain, Aug. 20, 1931; 514,432, Great Britain, Nov. 8, 1939; and Snook: *Treatise in Glass*, 1924, 1,417; briefed in Journal of the Institute of Metals, vol. 33, 1925, page 500.

Glass Compositions

High Index Optical Glass. Fig. 6. Patent No. 2,606,841. Filed May 31, 1949. Issued Aug. 12, 1952. One sheet of drawings. Assigned to Corning Glass Works by William H. Armistead.

This invention is a continuation of Patent No. 2,435,995 and relates to optical glass compositions which have an index of refraction for the D line (nD) greater than 1.60 and which are suitable for use in optical instruments.

The new glass, which is a transparent optical glass, is composed essentially of 3% to 70% BaO, 3% to 75% CdO, and 12% to 50% of a mixture of SiO_2 and B_2O_3, the total BaO, CdO, SiO_2 and B_2O_3 being at least 70%, the total BaO and CdO being at least 40%, and the remainder of the composition comprising compatible oxides. The refractive index (nD) is at least 1.60 and the dispersive index (ν) is greater than both $\nu = 202\text{-}100nD$ and $\nu = 111.4\text{-}46.6nD$.

The following glasses indicate the compositions which fall within the range of the invention:

	A	B	C	D	E	F	G	H	I	J	K
BaO	25	20	44	43	50	25	40	60	45	45	20
CdO	25	20	17	17	12	35	25	15	30	30	40
PbO	.....	10	.....	.....	.....	.....	.....	.....	.....	.....	20
Al_2O_3	.....	10	15.5	10	10	10	5	5	5	.....	2
B_2O_3	.....	10	23	16	8	15	10	10	10	10	7
SiO_2	40	30	.....	13	19	15	20	10	10	10	7
K_2O	10	.....	.....	.....	.....	.....	.....	.....	.....	.....	2
Na_2O	.....	.....	.5	1	1	.....	.....	.....	.....	5	2
nD	1.6105	1.6323	1.6530	1.6534	1.6538	1.6697	1.6777	1.6997	1.7179	1.7417	1.8712
ν	49	47	50.3	50.7	50.6	47	50	46	43	41	26

Fig. 6 illustrates the relationship between nD and ν for the glasses of the invention.

The patent contains eight claims and one reference was cited: 2,477,649, Pincus, Aug. 2, 1949.

Glass Wool and Fiber

Apparatus for Making Glass Fiber Strands. Fig. 7. Patent No. 2,607,167. Filed April 1, 1948. Issued Aug. 19, 1952. Assigned to Owens-Corning Fiberglas Corporation by Ivan G. Brenner.

Glass filaments are first produced in continuous lengths by apparatus 15 indicated in Fig. 7. The molten glass flows from the orifices 16 in small streams which are attenuated to form the primary filaments P. The mat removed from the collecting surface 41 is gathered into a strand 46 by a condensing turbine 47.

The strand or sliver delivered by the pull rolls is twisted to form twisted slivers or yarns by means of eye 49. From the eye 49 the yarn is collected on the traveller 50.

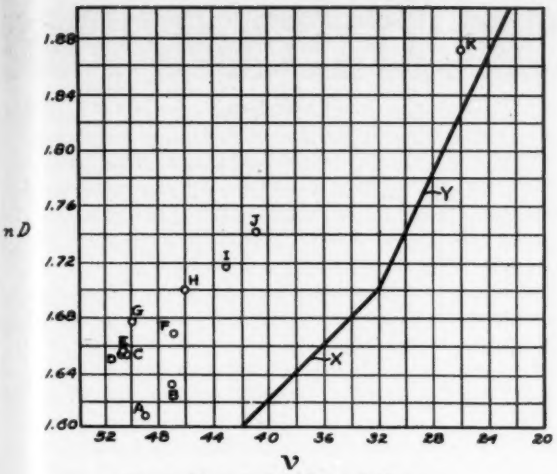


Fig. 6. High Index Optical Glass.

Sheet and Plate Glass

Apparatus for Producing Sheet Glass. Fig. 8. Patent No. 2,608,798. Filed Aug. 20, 1945. Issued Sept. 2, 1952. Two sheets of drawings. Assigned Libbey-Owens-Ford Glass Company by D. E. Sharp.

The object of this invention is to improve the quality of "sheet" glass or "window" glass by regulating the temperature and movement of the air and gases in the atmosphere surrounding the newly formed sheet. This regulation involves reversing the natural flow of air across the sheet by the use of controlled streams of conditioned air directed in the opposite direction of the natural flow.

In Fig. 8 the conditioning apparatus is adapted to the Colburn process. The apparatus is composed of a pair of oppositely disposed heat exchangers or coolers 25 and 26 arranged on either side of the sheet 16 and slightly above the surface of the molten glass 15. The coolers 24 also serve to condition the molten glass by reducing the temperature of the glass surface just before it is drawn into the sheet. Provision is also made to raise or lower these coolers as desired.

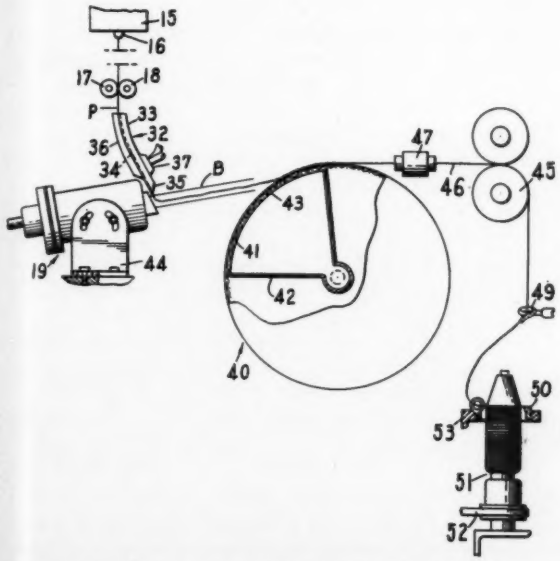


Fig. 7. Apparatus for Making Glass Fiber Strands.

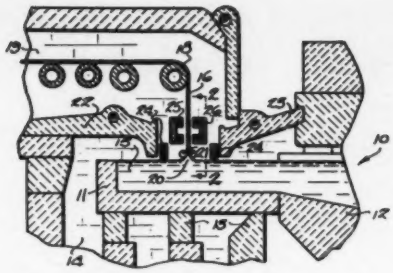


Fig. 8. Apparatus for Producing Sheet Glass.

Air compartments (not shown in drawing) are also made an integral part of the coolers and serve to regulate flow of air in the conditioning zone, as well as to provide fresh air within the zone when desired. A study of all the drawings is desirable to understand the full value of the patent.

The patent contains 11 claims and 11 references were cited.

Manufacture of Flat Glass. Fig. 9. Patent No. 2,607,168. Filed Aug. 1945. Issued Aug. 19, 1952. Two sheets of drawings. Assigned to Libbey-Owens-Ford Glass Co. by John L. Drake.

Improvements in the drawing of sheet glass are made so as to provide less distortion and wave in the sheet and at the same time provide a higher rate of drawing speed. Fig. 9 shows the essential characteristics of the Colburn type machines for drawing sheet glass. This invention provides a novel combination of air and water coolers or heat exchangers 25 and 26, mounted in horizontal alignment with one another at opposite sides of the sheet and normally midway between the molten glass 11 and the bending roll 16. This control feature makes it possible to exert a positive and uniform cooling action upon the glass sheet, and at the same time set up a controlled flow of air over the sheet surface, while it is being formed. Universally adjustable mountings (not shown) provide a means for shifting the position of the heat exchangers in order to provide still better temperature control.

The patent contains five claims and 12 references are cited.

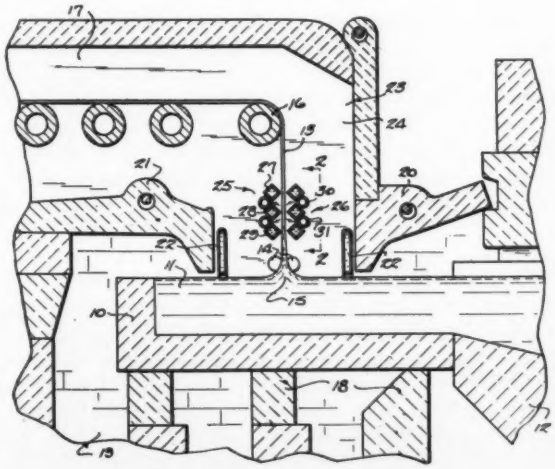


Fig. 9. Drawing of Flat Glass.

Improved Materials for Tank Blocks

Under oxidizing conditions at high temperatures, the most stable structures are given by the oxides of metals, the melting points of which range from nearly 3000°C. for thoria to 1710°C. for silica. Considerations other than that of high melting temperature, such as availability and cost, limit their use, however, so that the only oxides used in any quantity as refractory materials are those of silicon, aluminum, magnesium, zirconium, chromium and calcium, either alone or in combination. Busby and Partridge discuss such refractory materials from the viewpoint of glasshouse usage in the June 1952 issue of the *Journal of the Society of Glass Technology*.

There are about two broad types of clay substance. One contains about forty per cent of alumina and is of the Kaolin type; the other contains a much lower proportion of alumina and is represented by the structure of pyrophyllite and montmorillonite. On heating, clay substances break down at the comparatively low temperature of 550°-600°, but at higher temperatures the silica and alumina re-combine to form mullite, the stable constituent of silico-alumina refractories at high temperatures. A residue of free silica is left. Some of this silica is present in the vitreous state and serves to bind the crystals together to form a dense mass. Further, there is a eutectic mixture of mullite and silica containing 94.5% SiO_2, 5.5% Al_2O_3 with a melting point of 1550°, which is easily obtained in the glassy state.

Thus, most refractory materials consist of crystals set in a glassy matrix, the presence of which may be detected by X-rays or petrographic examination or by tests at high temperatures. X-ray examination reveals the presence of crystals and of a siliceous glassy matrix, even in some fusion-cast blocks. The crystals are usually of mullite and cristobalite, although the presence of silica in its low-temperature form, quartz, has been detected in poorly fired clay blocks, while corundum is also present in some "sillimanite" and fusion-cast blocks. These crystals, however, are set in a glassy matrix, and the behavior of a refractory is governed partly by the type of crystal present and partly by the character of this glassy matrix, the study of which has not yet received the attention it deserves. Further, fluxes are sometimes added to blocks to promote crystallization of the mullite, but it should be appreciated that they increase the proportion of the glassy matrix and also increase its fluidity. For example, if talc is added to a kyanite-clay mixture, the resulting block will contain cordierite. This cordierite ($2\,MgO \cdot 2\,Al_2O_3 \cdot 5\,SiO_2$) will be molten at the hot working face of the block, and thus, while being an excellent substance for promoting mullite crystallization and densification of the block, is harmful in that it lowers resistance to corrosion.

Little objection would be raised to this glassy matrix if it were either pure silica or the silica-mullite eutectic because these substances are very viscous at high temperature. Clay, however, is not a pure substance and contains other elements such as iron, calcium, magnesium and alkali metals and is closely associated with felspathic, micaceous and ferruginous minerals. When clay is heated to a high temperature, these impurities combine with the glassy matrix and reduce its viscosity. There are many instances of distortion of refractory material at high temperatures owing to the flow of this glassy phase; an example is the bulging of glasshouse pots. This glassy material can be drained from between the crystals. For example, material can drain away from tuckstones and being very corrosive can cut channels in the blocks below them.

A measure of the viscosity of this glassy matrix may be obtained from creep tests carried out on specimens in tension at temperatures in the region of 1350°-1450°. The test specimen is either cut from a large piece, i.e., a tank block, or extruded in rod form from the raw material. Two specimens, suitably fired, are then held horizontally in a platinum-wound furnace, a load being applied to one end. The furnace is maintained automatically at the required temperature and the extension of the specimen is measured by means of an optical lever. Test results indicate that in general the rate of corrosion decreases as the rate of creep drops.

An improvement in the tank-block material may be effected by a reduction in the proportion and an improvement in the quality of the glassy matrix. This may be accomplished by the use of pure clays and by adding a proportion of alumina, which can be made to combine with some of the free silica, thus increasing the proportion of mullite and reducing the amount of glassy matrix.

The corrosion test used by the authors consisted of determining the loss in volume of specimens after they had been rotated about their longitudinal axes while partially immersed in molten glass. In order to overcome several difficulties associated with this test, it was decided to estimate resistance to corrosion by: (1) the determination of the loss in volume after complete and also after partial immersion of the specimen in molten glass contained in platinum crucibles and (2) a calculation based on the change in composition of the solvent glass.

The specimens for immersion, which consisted of 1 cm. cubes, were suspended on platinum wires to which a platinum sinker was sometimes added. The platinum wire was fastened to a mullite tube across the top of a "globar" rod furnace. A platinum crucible containing a quantity of specially prepared cullet was placed underneath. The temperature was raised to the required value and time allowed for the cullet to fuse and become homogeneous. The siege of the furnace was then raised so that the suspended specimens became immersed in the glass about one inch from the bottom of the crucible. After the required time had elapsed, the siege was lowered and the specimens allowed to drain for 30 minutes. In order to determine the quantity of material cost due to corrosion, the specimens are weighed before and after immersion. Small quantities of glass still adhering to the specimens after corrosion were removed by careful grinding.

Specimens of a fire clay block, of a white block and of a fusion-cast block were subjected to corrosion by a soda-lime-silica glass for a standard time of 48 hours at various temperatures. Specimens of fire clay tank-

(*Continued on page* 555)

DRAKENFELD COMPANY OPENS NEW LABORATORY AND OFFICE

B. F. Drakenfeld & Co., Inc., has recently placed in operation its new modern office and laboratory facilities designed to coordinate development, production and sales as part of a stepped up program to provide for the growing needs of the expanding glass and ceramic industries.

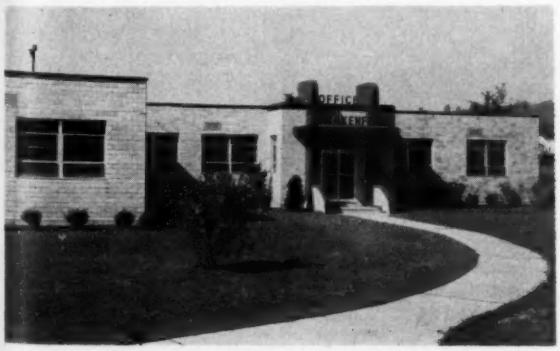
Located in Washington, Pa., where the company has manufactured colors for the ceramic industry for many years, the building adjoins a 61,844-square foot manufacturing plant, laboratory and warehouse, located only a short distance away. Housed in this newest addition to Drakenfeld's growing plant are administrative offices, and research and control laboratories of the Glass, Clay Wares, Porcelain Enamel Colors and the Miscellaneous Products Division.

In planning the construction of the new building, glass and ceramic products were given first consideration, Scott J. Courtney, Drakenfeld President, points out. Unglazed buff modular Dri-Speedwall tile was used for the exterior walls; the entrance and marquee are faced with architectural porcelain enamel, and the entrance rails are covered with porcelain-type mosaic glazed paver tile.

The building's roof has 1½ inches of Fiberglas insulation and the ceiling is covered with a 4-inch blanket of blown Fiberglas and finished with acoustic tile and recessed fluorescent lighting fixtures. The heating system is forced air and conditioned with electric precipitating filters.

The 8,800 square feet of laboratory space in the new building, plus the 4,600 square feet at the original plant, gives Drakenfeld what is believed to be the most extensive laboratory facilities of any ceramic color manufacturer. All corridor and interior walls of each individual laboratory are constructed of glazed facing-tile and each laboratory is complete in itself with the most up-to-date research facilities available. Some of the equipment was especially designed by Drakenfeld engineering personnel.

A group of six separate laboratories under the direction of Ray Andrews serves the Glass Colors Division. Four laboratories are available to the Clay Wares Colors Division, and two laboratories are maintained by the Porcelain Enamel Colors Division. Production control laboratories adjoin the office of D. Potts, Production Superintendent of glass and clay ware products.



Entrance to general offices at the new Drakenfeld office and laboratory building. Entrance and marquee are faced with architectural porcelain enamel. Porcelain type mosaic glazed paver tile covers the entrance rails. The exterior walls are unglazed light buff modular Dri-Speedwall tile.

Testing round for the Glass Color Department is found in this Research and Development Laboratory. Robert Murray is preparing a sample of glass color with oil, prior to screening upon glass, firing the color and then testing it for acid and alkali resistance. In the background, Boyd Frazee removes a sample from an electric furnace.

In addition to these research and production control facilities, four rooms in the new plant are equipped for grinding and mixing small laboratory batches of colors. In the factory proper, adjoining the laboratories, space has been made available for the experimental melting of fluxes and frits and for calcining pilot quantities of the glaze stains and oxides.

B. F. Drakenfeld & Company, Inc., is now in its 83rd year of operation. Its policy of emphasis on service is translated into action by a group of laboratory-trained engineers who divide their time between sales-service and laboratory work. In this way, the technical problems of customers and requests for on-the-spot assistance receive prompt attention from skilled personnel who are thoroughly familiar with the actual production of all products in the glass and ceramic industries.

Of the 130 Drakenfeld employees in Washington, 45 are technical and research personnel. Sixty-seven are process and factory workers and 18 do clerical work. Forty-four have been associated with the company in Washington for more than 10 years. The eight officers and ten key men responsible for research, production and service have an average of more than 25 years with the company.

Officers of the company, which maintains its executive offices at 45 Park Place, New York, N. Y., are: C. M. Beyer, Chairman of the Board; Scott J. Courtney, President; R. R. Shively and Irwin F. Zeiller, Vice Presidents; Harold D. Miller, Secretary; James T. Moriarty, Treasurer; Daniel E. McLaughlin, Assistant Secretary; and John G. Hoffman, Assistant Treasurer.

WESTINGHOUSE BUILDS UP LAMP PRODUCTION

As a means of building up the potential production of the Westinghouse Lamp Division plant at Fairmont, West Virginia, all manufacturing of tubular fluorescent lamps will be concentrated there.

Machinery has been transferred from the Bloomfield, New Jersey, headquarters of the Lamp Division for the manufacture of Circline fluorescent lamps, Circlarc decorative lamps and small-size fluorescent tubes used for special types of lighting.

Current Statistical Position of Glass

Employment and payrolls: Employment in the glass industry during July 1952 dropped to a preliminary 121,600. Compared with June employment of an adjusted 123,500, a drop of 1.5 per cent is shown. Employment during July 1951 was 121,200, a difference of only .3 per cent from that of July 1952.

Payrolls during July 1952 also fell off and were reported at a preliminary $34,471,979. This is 3.6 per cent less than the $35,797,298 paid out during June. Payrolls during July 1951 were $36,194,186, which is 4.7 per cent higher than for July 1952.

Glass container production, based on figures released by the Bureau of Census, rose during the month of August 1952 to reach a total of 10,700,149 gross. Compared with the previous month's production of 10,042,384 gross, an increase of 6.5 per cent is shown. Production of glass containers during August 1951 was 10,575,000 gross, which is 1.1 per cent less than for August this year. Total production of glass containers thus far this year is 77,688,318 gross. This is 7.3 per cent below the 83,809,917 gross produced at the close of the corresponding period in 1951.

Shipments of glass containers during August jumped 13.7 per cent to establish a new all-time high for shipments during a single month. The previous all-time high was during August 1950 when glass container manufacturers shipped a total of 11,302,038 gross. Shipments during August 1952 were 11,310,056 gross. During July 1952, 9,938,018 gross were shipped, while during August 1951 shipments were 10,822,367, which is 4.5 per cent below August this year. At the end of the January-August period, shipments of glass containers have reached a total of 77,218,910 gross. Compared with the corresponding period ending August 1951, when shipments had reached a total of 80,222,707 gross, it is shown that 1952 shipments are only 3.7 per cent off from 1951.

Stocks on hand at the close of August 1952 were 9,419,115 gross. This is 6.5 per cent less than the 10,106,700 gross on hand at the end of July and 6.4 per cent below the 10,102,186 gross on hand at the end of August 1951.

Automatic tumbler production rose 2.8 per cent during July to reach 4,965,904 dozens. This is an increase over the previous month's 4,830,500 dozens. During July 1951 production was 5,560,327 dozens. Shipments during July, however, fell to reach 5,244,624 dozens. This is 4.4 per cent below June shipments of 5,490,876 dozens. Shipments during July 1951 were 5,733,180 dozens. Stocks on hand at the end of July were 8,023,263 dozens, or 3.9 per cent below the 8,349,353 dozens on hand at the end of June. Stocks at the end of July 1951 were 11,768,503 dozens.

Automatic tumbler production during August continued to rise and reached a total of 5,832,795 dozens. This is an increase of 17.4 per cent over July. Production during August 1951 was 5,806,758 dozens. Shipments during August were 5,181,290 dozens. This represents a drop of 1.2 per cent from the 5,244,624 dozens shipped during July. During August 1951 shipments were 5,330,843 dozens. Stocks on hand at the end of August were 8,627,981 dozens, or 7.5 per cent higher than stocks at the end of July. Stocks at the end of August 1951 were 12,255,662 dozens.

Table, kitchen and household glassware: Manufacturers' sales of machine-made table, kitchen and household glassware during July were 2,944,891 dozens. This is an increase of 1.2 per cent over the 2,907,521 dozens sold during June. Sales during July 1951 were 2,766,096 dozens. At the end of the 12-month period ending July 1951, total manufacturers' sales have reached a 38,954,270 dozens. This is 4.3 per cent less than the 40,727,881 dozens sold during the corresponding period in 1951.

GLASS CONTAINER SHIPMENTS

(All Figures in Gross)

Narrow Neck Containers	August, 1952
Foods	1,186,151
Medicinal & Health Supplies	1,186,689
Chemicals, Household & Industrial	785,004
Beverages, Returnable	721,397
Beverages, Non-returnable	62,047
Beer, Returnable	183,705
Beer, Non-returnable	1,073,679
Liquors	804,147
Wines	316,087
Toiletries & Cosmetics	622,954
Sub-total (Narrow)	6,941,860
Wide Mouth Containers	
Foods	*3,042,414
Dairy Products	327,409
Medicinal & Health Supplies	352,859
Chemicals, Household & Industrial	143,035
Toiletries & Cosmetics	150,776
Packers' Tumblers	167,703
Sub-total (Wide)	4,184,196
Total Domestic	11,126,056
Export Shipments	184,000
TOTAL SHIPMENTS	11,310,056

* This figure includes Home Canning.

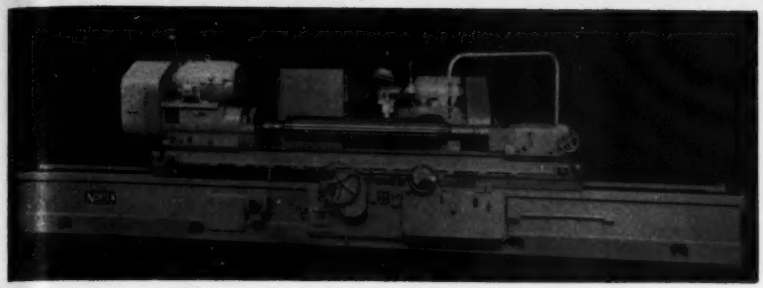
GLASS CONTAINER PRODUCTION AND INVENTORY

(All Figures in Gross)

		Production August 1952	Stocks August 1952
Foods; Medicinal & Health Supplies; Chemicals, Household & Industrial; Toiletries & Cosmetics	Narrow Neck	3,561,161	3,706,254
	Wide Mouth	*3,537,857	*2,990,512
Dairy Products		317,066	272,157
Beverages, Returnable		744,532	613,360
Beverages, Non-returnable		72,311	50,511
Beer, Returnable		173,390	231,292
Beer, Non-returnable		1,150,614	569,991
Liquors		666,906	620,285
Wines		308,866	262,546
Packers' Tumblers		167,446	132,207
TOTAL		10,700,149	9,449,115

* This figure includes Home Canning.

New Equipment and Supplies



NEW CYLINDRICAL GRINDING MACHINE

Norton Company, Worcester 6, Mass., has announced a new heavy-duty Norton Type C-2 cylindrical grinder built as a plain or semi-automatic machine in 18″, 24″ or 30″ swing, and in work lengths of 48″, 72″, 96″. 120″, 144″ or 168″, providing the means for lowering costs in grinding large cylindrical work. In addition to a fast grinding action, the Type C-2 offers new features that reduce costs by simplifying set-up and operation, and by requiring less maintenance.

With the new machine, set-ups are quickly made because all controls for feeds and speeds are adjusted at the front of the machine in the operating position. A feature is the combination graduated wheel feed handwheel and "click-count" indexing mechanism which readily indicates the amount of feed as the wheel is rotated past a fixed pointer, and permits settings of .0001″ in work diameter instantly and without visual attention.

With the use of a pre-set truing and grinding speed arrangement, table speeds for truing and grinding are independently adjustable and pre-set, and either speed is immediately obtained when desired by movement of a combination selector and table start-stop lever. No resetting of these speeds is necessary in the change from one to the other. Work-jogging control by means of a lever conveniently located near the operating position is also provided.

Other features include automatic or manual control of work rotation and coolant flow, and automatic adjustable wheel feed at table reversals with automatic resetting of the wheel head. Separate dwell controls for each end of the table reversal are also provided. All pumps and motors are placed in accessible locations outside of the machine. The Type C-2's grinding cycle operates with "one-lever" control. When operating on the electrically-timed cycle, the operator need only load the machine, touch a control lever and the machine will go through its cycle automatically.

EISLER NOVELTY GLASSMAKING UNIT

Eisler Engineering Co., Inc., 750 South 13th Street, Newark 3, New Jersey, has developed a group of machines for the reclaiming of bottles of all kinds for making glass novelties by using blown or pressed glassware. This unit is suitable for producing cups, beakers, drinking glasses and similar objects by cutting, glazing, forming, etc., of the glassware. The machine is suitable for other glass operations also.

The production output of the unit ranges from 100 to 150 per hour, depending on the diameter and wall thickness of the glass to be worked on. The unit consists of a wet type slicing machine #11-TU, a two-position glazing machine, #102-CO-2, and a combined gas booster and air blower, #71-NMB. Each of these machines is independently driven and can be used separately for many glassworking operations. The wet type slicing machine, #11-TU, with built-in water tank and direct connected motor driven water pump can be supplied with 12″, 14″ and 16″ diameter wheel sizes.

The reclaiming is done as follows: The bottle is cut apart on machine #11-TU and glazed on machine #102-CO-2. The mouth is made by hand with a carbon tool while the glass is still in a plastic state.

HEAT SEALING COMPOUND

Glyco Products Company, Inc., 26 Court Street, Brooklyn 2, New York, has announced an improved heat sealing compound called Acrawax C. With a high melting point (140°-143°C.—284°-290°F.), this synthetic wax raises the melting and cold flow points of such compositions without reducing adhesion and cohesion at low temperatures. Water, salt spray and chemical resistance are also increased.

A formulation for such heat sealing compounds is available. It has a high melting point (cold flow, 210°F. min.) and does not exhibit cracking or flaking at minus 45°F. The compound is non-corrosive and forms an efficient sealing barrier against leakage of air and moisture. It is resistant to water and salt spray.

The sealing compound is particularly useful for sealing lenses in optical instruments and other glass units. It is adaptable to a wide range of other sealing compounds where these properties are important.

SHORT-CYCLE PROCESS CONTROLLER

Minneapolis-Honeywell Regulator Company, Industrial Division, Wayne & Windrim Avenues, Philadelphia 44, Pa., has developed a short-cycle time-proportioning relay for controlling metallurgical laboratory-size furnace testing, nylon heat setting and linoleum curing.

The newly developed model has been added to the company's line in response to a demand for a pulse-type relay with a short cycle time for which the new model has proved effective in field tests.

CATALOGS RECEIVED

The Harshaw Chemical Company, 1945 East 97th Street, Cleveland 6, Ohio, has published a new booklet, "Harshaw Chemicals for Industry and Laboratory."

Following some general information about the company and some photographs taken at its research laboratories, the booklet continues with discussions of preformed catalysts, catalytic chemicals; electroplating salts, anodes and processes, fluorides; driers and metal soaps; pigments; ceramic opacifiers and colors; synthetic optical crystals; chemical commodities; glycerine; agricultural chemicals; and laboratory apparatus and chemicals. Each subject is discussed editorially and illustrations are presented.

North American Philips Company, Inc., Research and Control Instruments Division, 750 South Fulton Avenue, Mount Vernon, New York, has made available a new 4-page folder, "X-ray Fluorescence Analysis, Non-Destructive Testing at Shop Level."

Well illustrated, the folder is a reprint of an article published recently in a technical magazine. It describes the use of high intensity X-ray tubes and high efficiency Geiger counters for non-destructive identification of elements in 3 to 5 minutes after specimens are prepared.

The Moore Company, 1036 Quarrier Street, Charleston, W. Va., has announced publication of a 16-page, illustrated booklet, "The Design and Layout of Industrial Changerooms," which was written for the design engineer, safety engineer and consultant in changeroom problems.

Architectural standards, dimensions, equipment and safety are emphasized throughout, providing an easy reference for the planning engineer. The format is in two sections: the first containing changeroom standards and the second pertaining to designing dimensions and selected details. Several photographs of changerooms are included and sketches to indicate many of the details in layout of the entire room.

CALUMITE

has established itself as an outstanding glassmaking material—one that really meets the most exacting requirements in colored glasses.

This material has been proven to provide the following advantages:

(1) Low cost source of alumina

(2) Easier melting

(3) Uniformity

(4) Better glass quality and higher production

(5) Plants well located for low freight charges

(6) For the first time positive control can be maintained over quality since Calumite affords a method of mathematical approach to glassmaking

Many companies are finding that Calumite is the answer to their colored glass problems. Although supply is now limited, we hope to soon be able to meet the demand.

Your inquiries are solicited.

The Calumite Co.
HAMILTON, OHIO

CORNING RESEARCH CHEMISTS WIN AWARDS

Two research chemists of the Corning Glass Works will be awarded John Price Wetherill Medals by The Franklin Institute for their discovery of a new process for manufacturing glass. They are Harrison P. Hood and Dr. Martin E. Nordberg.

The citation accompanying the awards will read: "In consideration of the discovery of a truly novel process for the manufacture of unusual, high silica glasses comprising the vitrification of an insoluble phase of a heat-treated alkali-borosilicate glass after its soluble phase has been leached with inorganic acid."

The new glasses developed by Mr. Hood and Dr. Nordberg, which have a content of 96% silica, are exceptionally stable, have high softening points and expand very little at high temperatures. They can be produced with high ultraviolet light transmission or with exceptional electrical properties. These 96% silica glasses are among the group of low expansion products sold under the trademark Vycor.

During the first step in making one of these 96% silica glasses, the components for a special soft glass are heated conventionally in a tank furnace in order to produce a homogeneous melt. In this fused condition, the melt is fabricated into desired shapes, such as beakers, flasks, tubes and the like. Because of an appreciable shrinkage that occurs at a later stage, a resultant nine-inch dish must initially be made 10½ inches in diameter.

The second step, the most important aspect of this invention, is a heat treatment that varies in temperature and duration and that separates the glass into two distinct and sharply differentiated phases. The one, a continuous thread-like structure, is rich in boric oxide and alkali and is soluble in acids. The other, rich in silica, is insoluble in acids. When this important separation of these two phases occur, the glass becomes characterized by a bluish opalescence.

During the third step, the heat-treated glassware is immersed in an acid bath until the soluble phase is completely dissolved. Next, the glassware is washed for several hours in pure running water to remove every trace of the soluble material and other soluble impurities such as iron. This removal of the soluble substances leaves the silica phase a rigid and porous gel-like structure which retains the original shape of the glass article in every respect. The dried glass absorbs water and can be used as a drying agent for gases. The porous glass may also serve as a catalyst carrier, as an ultra filtering medium or as a membrane for gaseous separations.

The final step is to subject the glass article, which in essence consists of a porous siliceous shell, to a vitrifying heat treatment during which the insoluble phase is dehydrated and the cellular structure is collapsed into a non-porous, vitreous condition. During this state of dehydration and fusion, the article shrinks to about two-thirds its original volume as the top temperature of 1200°C. is approached.

APPOINTMENT BY GUSTIN-BACON

Gustin-Bacon Manufacturing Company has announced the appointment of F. H. Ebbert as Vice President and General Sales Manager.

Mr. Ebbert has been Vice President and Sales Manager of the company's Automotive Division since 1946.

the MAGIC GENIE of industry

• Like the magic genie of old, Harshaw Fluorides work capably and efficiently for many industries. They are used advantageously in numerous operations. The top ranking of Harshaw Fluorides is the result of rigidly controlled uniformity and quality.

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- Boron Trifluoride
- Boron Trifluoride Complexes
- Chromium Fluoride
- Fluoboric Acid
- Fluorine Cells
- Fluorinating Agents
- Frosting Mixtures
- Hydrofluoric Acid Anhydrous
- Hydrofluoric Acid Aqueous
- Hydrofluosilicic Acid
- Inorganic Fluorinating Agents
- Potassium Bifluoride
- Potassium Chromium Fluoride
- Potassium Fluoborate
- Potassium Fluoride
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- Silico Fluorides
- Sodium Fluoborate
- Zinc Fluoride

Available upon request . . . M. C. A. Safety Data Sheets SD-25 and H-10 furnishing essential information for safe handling and use of hydrofluoric acid.

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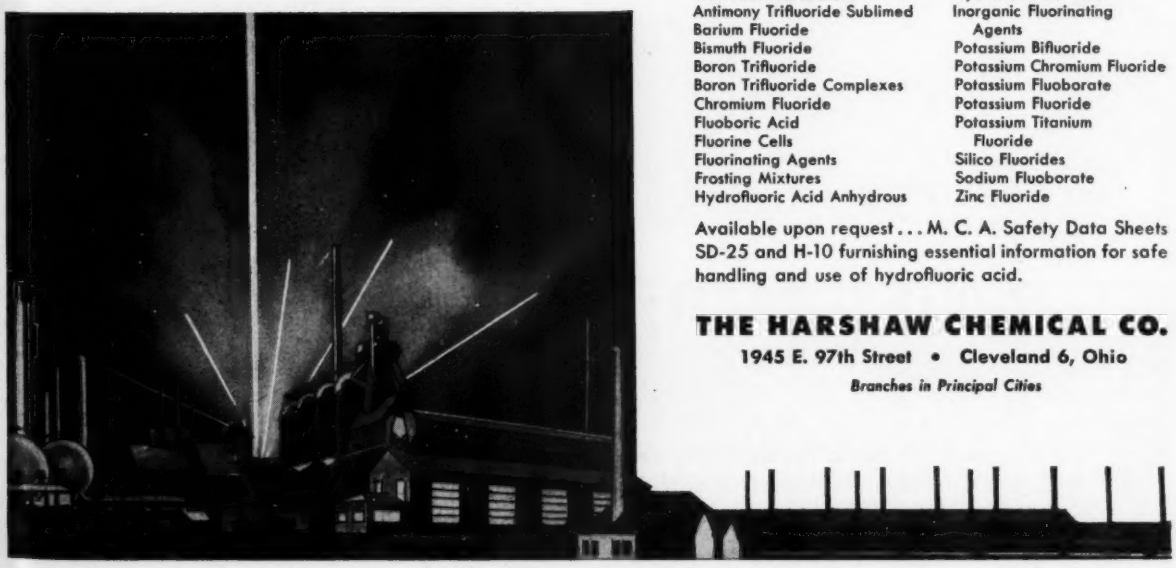

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For Better Cost Control . . .
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Precision weighing has proven a highly effective method for controlling costs and bettering quality in industry generally. Weighing of course is not new in the glass industry. Check-weighing at the hot end as well as the cold end (illustrated above) has been in effect for years. Today Shadograph Scales are presenting a new approach to high speed checking by increasing visible accuracy more than 300%. Illustrated below is a new Shadograph model for checking the smallest glass products now made. Available too are other models for ingredient compounding, displacement tests, large and small television tubes as well as many other products. There is an EXACT WEIGHT Scale for every precision weighing operation in the industry. Write for details to solve your problem.

Since very small glass containers demand a high degree of accuracy we recommend the Shadograph, both hot and cold end. The model #9061 (illustrated) can be built to specifications for checking the smallest glass containers now made. These scales give you better accuracy, frictionless shado indication which substitutes light projection indication for mechanical readings. Sensitivity is keen . . . too 2 Mg. All of these models are electrically operated, either DC or AC. Capacity to specifications.

EXACT WEIGHT SCALES
Industrial Precision
THE EXACT WEIGHT SCALE COMPANY
952 W. Fifth Ave., Columbus 8, Ohio
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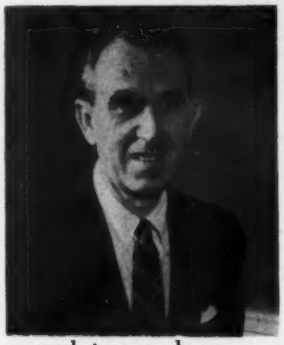
BALL BROTHERS NAMES MARKETING RESEARCH DIRECTOR



James L. Knipe, Vice President and General Sales Manager, has announced the appointment of T. Stanley Gallagher, of New York, as Director of Marketing Research for Ball Brothers Company.

Mr. Gallagher joined Ball Brothers following a four-year association with the Daystrom Furniture Division of Daystrom, Inc., as market research manager. Before his association with Daystrom, he was a marketing specialist first for a New York advertising agency and later for a firm of management engineers in Philadelphia.

Mr. Gallagher, Mr. Knipe stated, has assumed complete charge of the company's sales research section for the development of broader markets for present products and markets for new products.

YOUNG GUARD SOCIETY MEMBERS URGED TO RETURN FORMS FOR YEAR BOOK

Officials of the Young Guard Society are urgently requesting that members please return the envelope forms recently mailed supplying correct address and pertinent information which is requested for use in the 1953 Year Book. If this form is not returned, the information now in file will be used for the book.

MULLITE ADDS TO STAFF

The Mullite Refractories Company has announced the appointment to its organization of Edward L. Bohn.

Mr. Bohn will act as research consultant on furnace maintenance and construction. In this capacity, he will put his many years of experience in refractory material at the disposal of Mullite customers, in addition to developing applications in new fields where "Shamva" Mullite can solve severe heat problems.

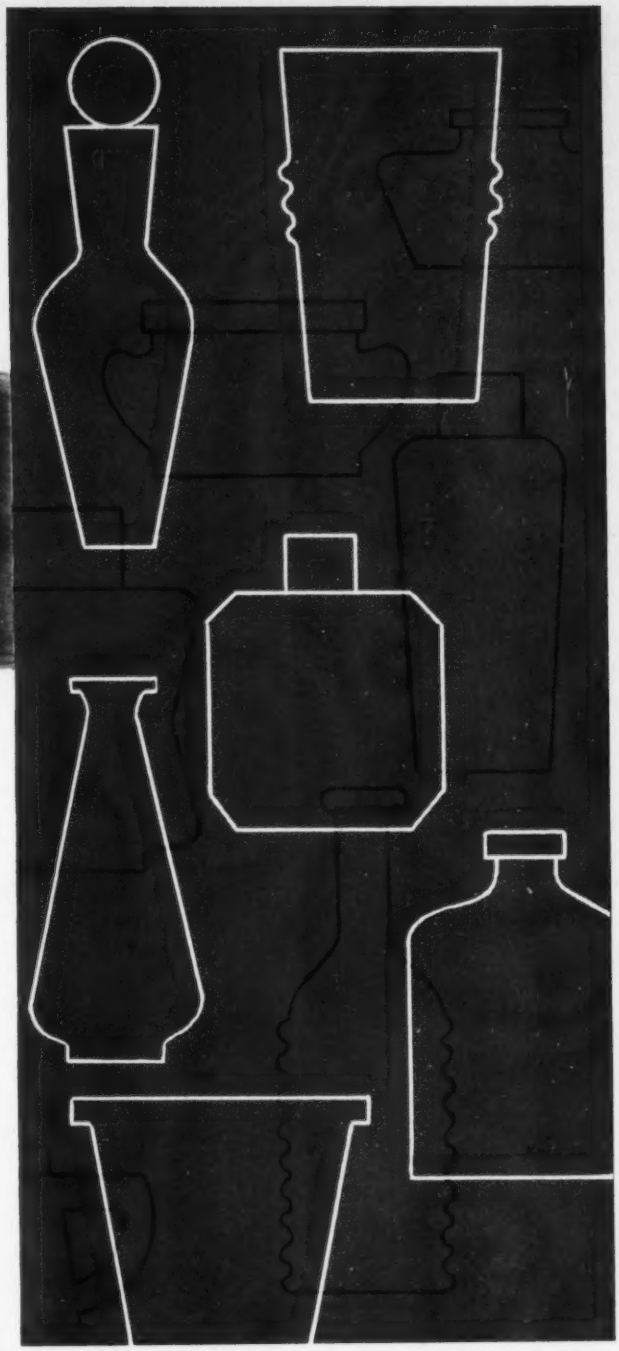
G-E GLASS MACHINE WORKS ADDS TO STAFF

Appointments of Kenneth D. Scott as Assistant Manager of General Electric Company's Glass Machine Works at Cleveland, Ohio, and E. A. Whitmore as Manager of the Kentucky Glass Works at Lexington, Kentucky, have been announced by Fred F. Harroff, President and General Manager of the company's Lamp Division.

Mr. Scott has been Manager of the Kentucky Glass Works since it began operations six years ago. He joined the firm at Schenectady, New York, in 1934 and moved to Nela Park in Cleveland the following year. He served as a member of the engineering staff until 1943 when he was named an engineer at the Mahoning Glass Works, Niles, Ohio.

Mr. Whitmore has been Assistant to the manager of the Kentucky Glass Plant for six years. He has been associated with General Electric for 15 years, starting at Schenectady and transferring to the Niles Glass Works, Bridgeville, Pa. Glass Works, and later to glass manufacturing at Nela Park.

"the shape of things to come . . ."



For over 30 years Overmyer has engineered the moulds that gave existence to a myriad of glass container shapes and forms as they came from the designers' drawing boards . . . translating ideas into actualities! And each mould met the Overmyer standard of quality — absolute uniformity and capacity. We can only conjecture on the shape of things to come . . . the shape of the glass containers of the future that will draw their first breath of life from an Overmyer mould. We are certain, however, that regardless of their complexities, Overmyer Engineering will be working hand-in-hand with the Glass Industry toward a well-founded and successful solution.

Overmyer
A PART IN THE PROGRESS OF GLASS

MOULD COMPANY, INC.

General Offices, Main Plant and Foundry Division: Winchester, Indiana

Eastern Plant: Greensburg, Pennsylvania • *Western Plant: South Gate, California*

COLORATION OF GLASS . . .

(*Continued from page* 514)

important process which may be called *photosensitization*. The metallic atoms may coagulate under heat treatment to yield visible color, or may be detected through their fluorescent or other behaviors. When the excited electrons formed by the passage of radiations return to the lower excited states or the ground state, optical radiations of definite wavelengths are emited. The phenomenon is called *luminescence*, which includes phosphorescence and fluorescence. Ordinary glasses, like crystals, contain many imperfections such as vacancies (sites) where a positive or negative ion is missing. The displacement of atomic nuclei through recoiling or direct ejection from the passage of radiation produces more vacancies. Some of the negative ion sites serve as an excellent surrounding for a free electron to dwell. The net result of the electron-negative ion vacancy combination gives rise to the formation of a new chemical substance which possesses typical optical absorptions of its own. If the absorptions are in the visible region, color results. This is the so-called *color-center formation*. Some of the free electrons during the passage of radiation may be trapped in some location near impurities so that they could not jump easily to the lower levels. However, by the addition of the small amount of extra energy supplied by infrared radiation or heat, they may be sent to slightly higher levels which are radiating levels. Once in these levels, the electrons are capable of transition to lower or ground state with the accompanying emission of light. This phenomenon is called *thermoluminescence*. The irradiated glass will emit light upon heating. If the extra energy required is supplied by mechanical distortions, such as crushing, application of stress, etc., the process of the light emission is called *triboluminescence*. Last of all, some energy will be eventually degraded into long wavelengths in the form of *heat*. The liberation of heat by fission fragments in nuclear explosion or in nuclear power engines should illustrate the importance of this phenomenon. The famous experiment of C. D. Ellis and W. A. Wooster[76, 144] on the thermal determination of total heat content of a β-emitting substance was the foundation for the suggestion of the existence of neutrinos. However, at low radiation intensity ($< 10^{10}$ r), such as that considered in this study, the heat effect is not significant.

The subject of luminescence of glass with the ultraviolet radiations as the primary source of excitation have been treated extensively by Weyl[186, 187], and in some specific instances by Kreidl[100]. The subject matter will not be duplicated here other than to mention that the luminescent effect of the passage of the radiation in a crystal has assumed a very significant role in the modern detection of nuclear radiations. The now familiar scintillation counters are built on the luminescent properties of such crystals as NaI (Tl-activated), anthracene, stilbene, ZnS (Ag-activated), etc. The fluorescence of glass is relatively weak as compared with that of crystals, although Albrecht and Mandeville[1] have used an ultraviolet sensitive Geiger counter to detect the fluorescence of the Corning No. 974 ultraviolet transmitting glass and other common glass in the wavelength region 3340-4350 A when these glasses were bombarded with α-particles. Whether the scintillation behavior of a glass will assume significance, only future investigation will tell. From a practical point of view, glass scintillators are important because the large pieces desirable in the interception of radiations can be more easily made from glass than in the form of a single crystal. In passing it may be interesting to note that when the velocity of the charged nuclear particles is greater than c/n where c is the velocity of light and n is the refractive index of the glass, an instantaneous emission of visible light in a definite prescribed direction is observed during the passage of the radiation. This is the so-called Czerenkov phenomenon and is to be distinguished from the fluorescence.

Our discussions will largely be centered around the subjects of solarization, photosensitization, color-center formation and thermoluminescence. There is little information on triboluminescence at present.

It is also important to note here that the effect of discoloration is most severe when the glass has high absorption coefficients for the radiations in consideration. In that respect, references may be made to the work of Sun and Sun[179, 180] on the absorption of electromagnetic radiations and neutrons by glass. Brewster[25] has recently extended the tabulation of absorption coefficients for x- and γ-rays.

(*To Be Continued*)

IMPERIAL GLASS ESTABLISHES FIBER GLASS SUBSIDIARY

It has been announced that FiGlass, Incorporated, Bellaire, Ohio, had been granted a certificate for accelerated tax amortization under Section 124a of the Internal Revenue Code in an amount totalling $1,336,000 in connection with the creation of new facilities for the manufacture of fiber glass.

FiGlass, Incorporated, has been revealed to be a wholly-owned subsidiary of the Imperial Glass Corporation. C. W. Gustkey is President and Treasurer, C. J. Uhrmann is Vice President and General Manager, and K. G. Cooper is Secretary.

It has been announced that the pilot plant is in operation behind closed doors in the Imperial building producing sample and test quantities of fiber glass for plastic reinforcement and other varied uses.

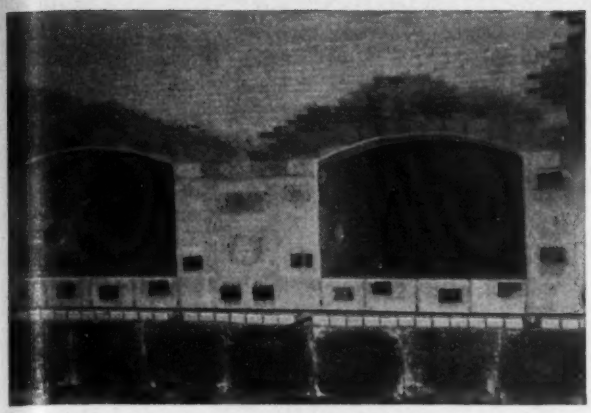
PLANT MAINTENANCE CONFERENCE TO BE HELD IN JANUARY

In recognition of sky-rocketing costs of maintenance in the chemical industry and the added engineering and personnel problems due to increasing mechanization, it has been decided to set aside two sessions of the forthcoming Plant Maintenance Conference exclusively to a discussion of chemical plants.

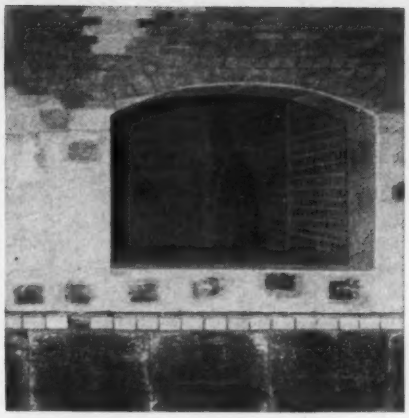
The Conference is to take place at the Public Auditorium, Cleveland, January 19 through 22, concurrently with the Plant Maintenance Show.

The sessions devoted to the chemical industry will be round-table discussions, conducted by a chairman and a discussion leader.

• The Directors of Laclede-Christy Company have declared a quarterly dividend of 35¢ per share on the common stock, payable September 30, 1952, to stockholders of record as of the close of business September 15, 1952.

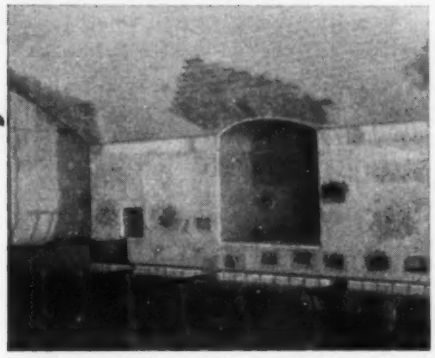


This is the 1st and 2nd port area of a gas-fired, 4-port furnace used to produce flat glass.



View of 3rd port

Once Again—



View of 4th port

"MONOFRAX" REFRACTORIES *picked for all heavy duty areas*

This photo shows part of a flat-glass furnace (4-port), rebuilt recently by one of the nation's largest glass producers. The significant point about this installation is that the most vulnerable furnace areas — both at the metal line and above — are completely constructed of MONOFRAX fused cast refractories. The entire 18" top course of the tank, from doghouse to machines, is made of our Type K MONOFRAX composition. And in the superstructure our Type H composition is used from the backwall through the last port — for the breastwalls, plate blocks, and the port assemblies, including jambs, arches, bottoms and burner blocks.

It is significant that this company, with its several plants, has had experience with many different refractory materials. Yet, it was the MONOFRAX refractories, you note, that were selected to take the heavy punishment in this furnace. (Incidentally, this company is now using MONOFRAX refractories at this and other plants, and has just placed another large order for a 7-port furnace.)

So, keep these high-alumina fused cast refractories in mind. There are 3 distinct compositions, each of which excels in certain applications. Together they make an unbeatable team for all your heavy duty needs. Remember: MONOFRAX refractories made by The Carborundum Company.

For further data address Dept. L-102, Refractories Div., The Carborundum Co., Perth Amboy, N. J.

Fused cast refractories by

CARBORUNDUM

Trade Mark

for long campaigns . . . quality glass

"Carborundum" and "Monofrax" are registered trademarks which indicate manufacture by The Carborundum Company.

LIBERTY GLASS MODERNIZES FACTORY FACILITIES

Approaching its 35th anniversary, Liberty Glass Company is in the process of further modernization of its factory facilities at Sapulpa, Oklahoma. Enlarged and improved in an expansion program completed during the last five years, according to George F. Collins, Jr., President, the Liberty plant's current improvements will further increase its efficiency and production capacity at a cost in excess of $500,000 during the next year.

The new automatic batch plant towers 150 feet in the air. The glass furnaces at the plant will be elevated to improve working conditions, as well as to better accommodate the latest type bottle forming machines. Additional forming machines will be installed. Warehouse, loading dock and power plant facilities will be enlarged and modernization will include new forming processes.

AMERICAN NEPHELINE COMPLETES EXPANSION PROGRAM

It has been announced that American Nepheline Limited is now equipped to handle a considerable tonnage of two different grades of glass material, depending on the iron oxide content. This is the result of recent plant expansion and improvement which has been completed.

The two grades of material have the same chemical analysis. The low iron oxide product is for use in flat glass and the higher iron oxide product for amber and emerald green glass. In order to carefully control the physical characteristics of both of these products, a very complete dust collection system is being installed to remove from the concentrate a great deal of the objectionable fines. The installation of the dust collection equipment is considered to be the final step in the completion of the program.

S. T. ORR NAMED TO WYANDOTTE PRESIDENT'S STAFF

Stephen T. Orr, Vice President of Wyandotte Chemicals Corporation and for twenty-five years in charge of the company's manufacturing and operating activities, has been made a member of the president's staff with the rank of Vice President, Robert B. Semple, President, has announced. Mr. Orr is succeeded in his manufacturing responsibilities by Frank Wolcott, his immediate assistant, who becomes General Manager of Manufacturing, Michigan Alkali Division.

Mr. Orr, who was highly commended in the statement by Mr. Semple concerning his appointment, joined the Michigan Alkali Division in 1906, succeeding his father, William T. Orr, as General Manager.

PITTSBURGH CORNING APPOINTMENT

The appointment of J. R. Nicholson as Manager of Glass Block Sales has been announced by Paul D. Japp, General Sales Manager of Pittsburgh Corning Corporation.

Mr. Nicholson will direct all phases of the company's glass block sales activities. He has been associated with the firm since 1949, serving as a field representative and more recently as Manager of glass block distributor sales.

• DESIGN
• ERECTION
• OPERATION

of Glass Plants

DOMESTIC AND FOREIGN

Complete Glass Plants and Equipment, Batch Systems, Glass Melting & Sodium-Silicate Furnaces, Batch Feeders, "Schmid" Mechanical Gob Feeders, "Liberty" Pneumatic Gob Feeders, Automatic Handling Equipment, Stackers, Lehrs, Machines, etc. for manufacture of containers, flat glass, pressed ware, and tubing. Furnace Repairs and Rebuilding. Process Engineers.

ARTHUR W. SCHMID COMPANY

ENGINEERS AND CONTRACTORS

INVESTMENT BUILDING, PITTSBURGH, PA.

Cable address: "Schmid" Pittsburgh
"Glasprint" New York

International Division: 444 Fourth Avenue
New York 16, N. Y.

SHAMVA®

MULLITE BRICK

BOOSTS PRODUCTION

Because **SHAMVA**

increases tonnage per campaign

Shamva Mullite allows higher operating temperatures and quicker heat delivery to the charge. Shortened heat time and low heat conductivity result in more tonnage per campaign.

Because **SHAMVA**

reduces shutdowns

Shamva Mullite Brick have a greater wear resistance and longer service life because of an ideal combination of physical properties.

1. High Fusion Point (3335°F.)
2. High Softening Point (Over 3000°F.)
3. Low Coefficient of Expansion (3.66 x 10^{-6} per °C.)
4. Anti-Spalling (No spalling A.S.T.M. test)
5. High Load Bearing Strength (0.1% A.S.T.M. test)
6. Low Heat Conductivity for greater furnace efficiency.

Remember Mullite is the only alumina-silica refractory stable at high temperatures . . . and for mullite the buy-law is **SHAMVA**

THE MULLITE REFRACTORIES CO.

SHELTON, CONN.

THERMAL EXPANSION OF GLASSES . . . *(Continued from page 531)*

System No.	System	Investigator	Weight Per Cent Composition					Coefficient of Expansion ($\alpha \times 10^7$)	Temperature Range (°C.)
71	$RO\text{-}B_2O_3\text{-}Al_2O_3\text{-}SiO_2\text{-}P_2O_5$	F. Drexler & W. Schutz Glastech. Ber., *24*,172 (1951)	RO	B_2O_3	Al_2O_3	SiO_2	P_2O_5		
			RO = K_2O 20	10	30	20	20	127.3	
			MgO 20	10	30	20	20	50.9	
			CaO 20	10	30	20	20	64.1	
			BaO 20	10	30	20	20	70.3	
			ZnO 20	10	30	20	20	34.2	
			La_2O_3 20	10	30	20	20	34.2	
72	$Na_2O\text{-}B_2O_3\text{-}Al_2O_3\text{-}PbO\text{-}P_2O_5$	J. E. Stanworth J. Soc. Glass Tech., *30*,281T (1946)	Na_2O	B_2O_3	Al_2O_3	PbO	P_2O_5		
			18	14	15.5	19	33.5	143‡	0-200
			14	14	15.5	23	33.5	124	
			14	7	15.5	30	33.5	141	
73	$MgO\text{-}CaO\text{-}B_2O_3\text{-}Al_2O_3\text{-}P_2O_5$	A. E. Dale & J. E. Stanworth J. Soc. Glass Tech., *35*,185T (1951)	MgO	CaO	B_2O_3	Al_2O_3	P_2O_5		
			13.6	5.0	29.1	24.7	27.6	56	0-400
			13.6	5.0	32.1	24.7	24.6	55	
			13.6	5.0	35.1	24.7	21.6	58	
			13.6	5.0	38.1	24.7	18.6	56	
			13.6	5.0	35.1	21.7	24.6	57	
			13.6	5.0	38.1	21.7	21.6	61	
			13.6	5.0	41.1	21.7	18.6	56	
			13.6	5.0	38.1	18.7	24.6	57	
			13.6	5.0	41.1	18.7	21.6	56	
			13.6	5.0	44.1	18.7	18.6	56	
			13.6	5.0	44.1	15.7	21.6	58	

‡Calculated from enlarged drawings kindly supplied by Dr. Stanworth.

J. GORDON KING NAMED TO MANAGE O-I KAYLO DIVISION

J. Gordon King, Vice President of Owens-Illinois Glass Company and Manager of glass container production, has been named General Manager of the Kaylo Division. He succeeds Thomas A. Collins, who is resigning to accept a position with another company.

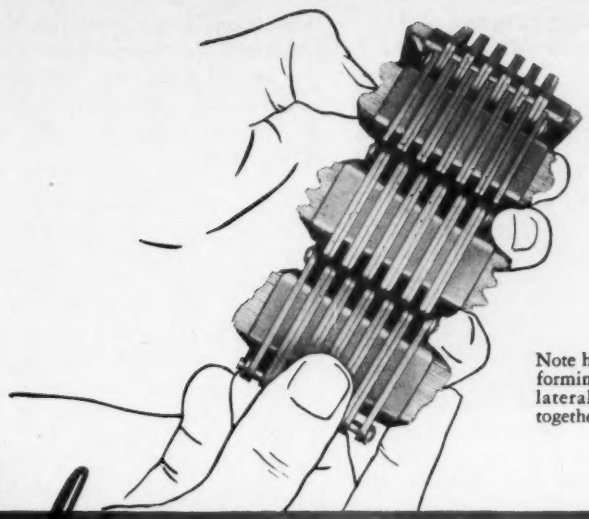
Mr. King, a graduate of McGill University, joined the General Manufacturing Division of Owens-Illinois in 1932.

Anhydrous: Technical Grade
Granular

Hydrate ($Na_2B_4O_7 \cdot 10H_2O$):
USP and Technical Grades
Regular Granular
Fine Granular
Powdered
Borax Glass (30 mesh)

STAUFFER CHEMICAL COMPANY

420 Lexington Avenue.....New York 17, N. Y.
221 No. LaSalle Street.....Chicago 1, Ill.
824 Wilshire Boulevard.....Los Angeles 14, Cal.
326 South Main Street .....Akron 8, Ohio
636 California Street.....San Francisco 8, Cal.
Houston, Tex. • N. Portland, Ore. •
Apopka, Fla. • Weslaco, Tex.



Note how slats in the self-tooth-forming chain are free to move laterally — either singly or together.

Only **the P.I.V. variable speed drive uses**

SELF-TOOTH-FORMING CHAIN

to give you positive, stepless speed changing

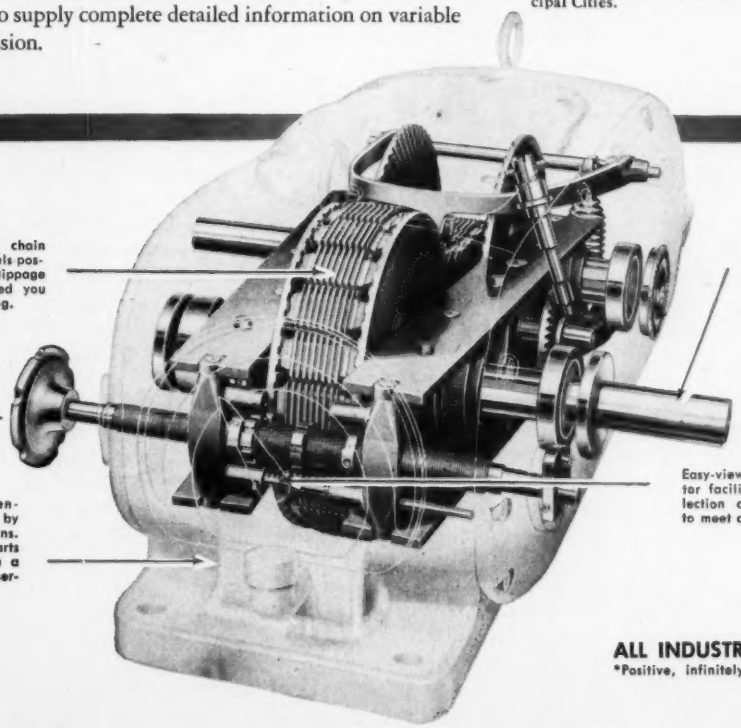
The operation of Link-Belt's P.I.V. Variable Speed Drive is not dependent upon friction for power transmission.

That's because only Link-Belt's P.I.V. has the self-tooth-forming chain that allows *positive*, stepless speed adjustment.

If you've been looking for exact speed changing that will deliver full rated horsepower to your machines, it will pay you to call your nearest Link-Belt branch office, as our representatives are equipped to supply complete detailed information on variable speed transmission.

LINK-BELT P.I.V. VARIABLE SPEED DRIVE

LINK-BELT COMPANY: Chicago 9, Indianapolis 6, Philadelphia 40, Atlanta, Houston 1, Minneapolis 5, San Francisco 24, Los Angeles 33, Seattle 4, Toronto 8, Springs (South Africa). Offices, Factory Branch Stores and Distributors in Principal Cities. 12,272



Self-tooth-forming chain grips toothed wheels positively without slippage — gives the speed you need at any setting.

An infinite number of positive, stepless speed adjustments may be made with manual, electric, pneumatic or hydraulic controls.

All-metal, totally enclosed — unaffected by atmospheric conditions. All vital operating parts splash-lubricated from a common housing reservoir.

You can get minute speed changes and maintain them accurately while operating under full load.

Easy-view speed indicator facilitates speed selection and adjustments to meet all requirements.

ALL INDUSTRY USES P.I.V.*

*Positive, infinitely variable

L. J. HOUZE CONVEX GLASS COMPANY CELEBRATES ITS 50th YEAR

L. J. Houze, Sr.

R. J. Houze

With a meeting of employees and their families, and friends, the L. J. Houze Convex Glass Company celebrated its fiftieth year in the glass business on September 25. A specialist in colored glass, the company's principal product is sunglass lenses.

The establishment of the glass company came about in 1899 when a group of window glass workers in Jeannette, Pa., among whom were Jules J. Quertinment and Joseph C. Mayer, decided to build a glass factory organized on a cooperative basis. In that town they found it impossible to buy a suitable site with adequate transportation facilities and the new company agreed to locate in Point Marion, Pa. Leon J. Houze, Sr., who had built the first cooperative window glass factory in Meadville, Pa., soon became associated with the new project. The temporary organization, a limited partnership, was made permanent on June 9, 1900, and was incorporated as the Jeannette Glass Company, Ltd.

In 1902, Leon Houze, Sr., and several associates resigned from the company to form a new organization in which all the stockholders were workers in the concern. It was incorporated as Federated Window Glass Company and began operations in the fall of 1902. In 1911, Mr. Houze, with his son Roger J. Houze, formed a partnership known as the L. J. Houze Convex Glass Company. The firm bent common window glass into convexed portrait glass and from this operation came the name of the company, which has been continued to the present time.

The need for portrait glass became so great that in 1914 Mr. Houze and his son, Roger, organized the Houze Window Glass Company to supply flat window glass for bending. It was during this same World War I period that a market for colored goggle glass and transparent colored sheet glass was created—all such glass having been imported up until that time. Pressed glassware was soon added to the line and all three companies prospered until the invention of glass blowing and drawing machines brought about a complete change in manufacturing methods for sheet glass and replaced the production of window glass by the hand blown process.

The colored glass venture was highly successful, but operations were handicapped by a lack of natural gas, the gas field being owned by the Federated Glass Company. For this, as well as for other reasons, it was deemed advisable to merge the three companies under the name of L. J. Houze Convex Glass Company and, at the same time, production of window glass was discontinued. The merger became effective on July 5, 1923 and at that time there were three men who had been workers and stockholders throughout the existence of the organizations: Leon J. Houze, Jr., Frank Criner and Henry Bertin.

The principal product of L. J. Houze Convex Glass Company is sunglass lenses. Colored lenses, in hundreds of shapes, sizes and colors, are produced by the millions each year for America's leading sunglass manufacturers. Each Houze lens undergoes six rigid tests from the time the drawn sheets leave the tower of the Fourcault machines, each of which produces three tons of glass daily for lenses, or roughly three miles of glass per day. In addition, periodic tests are conducted by technicians and checked on a lensometer, a device used by opticians to test corrective lenses. The company also produces colored optical glass blanks for grinding and polishing, ground and polished colored optical lenses, and ground and polished colored flat lenses, thereafter thermally curved.

STAFF CHANGES AT BROCKWAY

Brockway Glass Company has announced the appointment of J. E. Kerwin to their Kansas City sales office. Mr. Kerwin was formerly with the Nesbitt Fruit Products Incorporated.

Also announced were the following transfers in the Sales Department: Ralph Nash from Memphis, Tennessee, to Cincinnati, Ohio; Harry Bruno from Atlanta, Georgia, to Buffalo, New York; Richard Sturm from Western Pennsylvania to Atlanta, Georgia; and Vincent LePore from Philadelphia, Pa. to Los Angeles, California.

At the same time, Brockway announced additions to its sales staff as follows: Lincoln Key in New York, N. Y.; Richard C. Yardley in Philadelphia; Marshall Hartless to Baltimore, Maryland; Byron P. Jones to Muskogee, Oklahoma; and James R. McGoldrick to St. Louis, Missouri.

L-O-F PRODUCT DEVELOPMENTS

An additional series of glass textile yarns, doubling the number of specified types produced, has been announced to the weaving trade by the Fiber Glass Division of Libbey-Owens-Ford Glass Company.

It has been reported that the Parkersburg, West Va., factory is now producing "225" industrial yarns, a considerably finer type than the "150" series with which the company started its operations a few months ago. The new yarns are used largely in industrial cloth, electrical insulation, plastic laminations for aircraft construction, tape and similar applications.

Three additional stock sheet sizes of Mirropane, the transparent mirror made by L-O-F, have also been announced. The new sizes are 12 x 20 inches, 20 x 20 inches and 20 x 30 inches. This now provides seven stock sheet sizes for the mirror.

A wider range of standard sizes of its new Securit interior glass door has also been made available by Libbey-Owens-Ford. The new patterned glass door is a 3/8-inch Muralex glass patterned on both surfaces. It is heat-treated by the Securit process to make it three to five times stronger than conventional glass of the same thickness.

RESEARCH DIGEST . . .

(*Continued from page* 536)

block material of reasonably good quality were completely dissolved in less than 48 hours at 1375°, while specimens of fusion-cast mullite material were corroded away at a temperature of 1425° under these conditions of test. The latter possessed about the same resistance to corrosion as the well-fired purer clay blocks developed by the authors. The pure clay block is made from china clay to which alumina is added and the block is fired until it consists of well-developed needles of mullite bonded with a siliceous glassy phase. The addition of alumina increases the amount of mullite and reduces the proportion of glassy bond.

The oxides of silicon and aluminum in the form of clay are not the only ones available for making tank blocks, blocks containing zirconia, alumina and spinels having been placed on the market during the past decade.

A refractory mass consisting of either zircon or zirconia crystals may be developed at will, depending on the composition of the bond and the firing treatment, the zirconia arising from the breakdown of the zircon, $ZrSiO_4 \rightarrow ZrO_2 + SiO_2$. It is possible to produce these materials by casting from fluid slips. Although the firing temperature needed for production of dense blocks is high, it is within the bounds of commercial possibility. Specimens of these blocks have given encouraging results in laboratory corrosion tests.

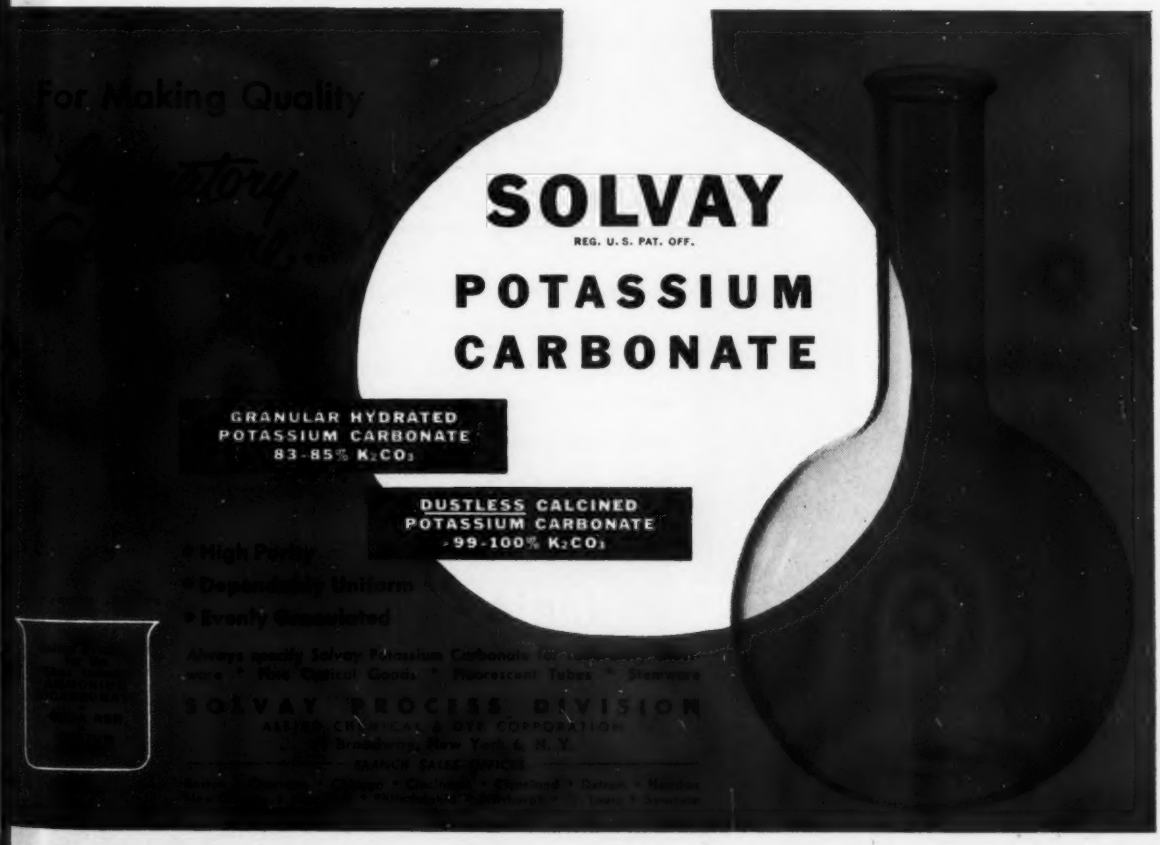
The fusion-cast tank block is a challenge to those materials made by conventional methods, but the authors conclude that their preliminary work has shown that it should be possible to produce blocks of equal corrosion resistance by using conventional slip-casting techniques and adequate firing.

ARMOUR RESEARCH FOUNDATION REVEALS NEW CONSTRUCTION MATERIAL

A new construction material with many potential applications in the building trades has been described by a ceramics expert at Armour Research Foundation of Illinois Institute of Technology. The material, result of four years of effort, consists of tiny glass balloons, about the size of grains of sand, according to John Neff, assistant chairman of the Ceramics and Minerals Research Department at the Foundation.

Trade-named "Kanamite" by Kanium Corporation, Chicago, which sponsored the development work at the Foundation, the material is a fine-grain, lightweight aggregate made by blowing up individual grains of clay in a special furnace. Individual particles of the new material are almost spherical. Their size varies with the raw material and the method of processing. Sizes from .0116 inch to .0069 inch in diameter seem most useful.

The material is made in mid-air, in the fiery atmosphere of a special furnace. Ground and screened clay is fed into the top of a vertical furnace. The individual grains of the raw material melt in the approximately 2700°F. heat of a gas-air flame as they fall through it. Gases given off by the tiny melted blobs at the correct instant inflate them into hollow spheres. The little glass balloons drop out of the flame and cool during the remainder of their fall. They are collected at the bottom of the tall furnace.



JENA GLASS WORKS OPEN NEW PLANT

For nearly a century, the Jena Glass Works Schott & Gen. have been noted for the manufacture of the finest optical glass. The Jena plant was originally liberated by the U. S. Army Forces, and before the Russians took over, about 180 of the top personnel, including scientists, were evacuated to the Western Zone of Germany.

Starting from scratch, this group of men rebuilt and put into operation smaller plants there, particularly for the production of optical glass. Now, aided by capital from the United States under the Marshall Plan, a new plant was erected near Mainz. Recently the opening of the first section was attended by important American, French and German officials.

The section of the plant now in operation was built in ten months. When the entire plant is completed, 4,000 people will be employed. Designed along modern lines and furnished with the most advanced equipment, the new plant will enable Schott & Gen. to greatly increase production of fine optical glass and to maintain the high standard of excellence for which the organization is famous.

LOF INSTITUTES COLOR LABELS FOR PRODUCT IDENTIFICATION

A new system of labels for glass leaving the factories of Libbey-Owens-Ford Glass Company which uses color to identify the basic types of glass, thicknesses and qualities, all incorporating the new LOF glass trademark, has been developed and is now in use.

More than 100,700,000 labels were used by LOF glass in the last year, which is indicative that labeling is important for the employees in the plants, the distributors and dealers, as well as the customers.

The basic LOF colors are blue, white and red and have been selected to identify the basic products—polished plate glass, sheet or window glass, Vitrolite.

Take window glass or sheet glass labels with white background, for example. The packer, the glazier or the customer can now tell at a glance the thickness by the color of the printing on the white label. Gray means thin picture glass, red is single strength, blue is double strength, brown labels 3/16-inch sheet, orange means 7/32-inch sheet, purple is for 1/4-inch sheet, and green marks the new heat-absorbing sheet glass.

Another example are polished plate glass labels which are in blue with lettering in white. Quality is shown in an identifying block in the lower part of the label with red denoting silvering, light blue for mirror glazing, and white for glazing quality.

DIAMOND ALKALI APPOINTMENTS

Managerial appointments of two important branch sales offices of Diamond Alkali Company have been announced by W. H. McConnell, Director of Sales.

Effective November 1, Earl J. Mills will become Manager of the Chicago branch sales office, succeeding the late Charles W. Klaus, and John W. Kennedy will be Manager of the Southwest District sales office, which has its headquarters at Houston, Texas.

In container ware batch
B_2O_3*
Speeds melting rate
Speeds fining rate
Improves durability . . . appearance
Container ware manufacturers are becoming increasingly aware of the merits of B_2O_3 as a minor constituent. A primary source of supply is the Pacific Coast Borax Co. with its continuous record of supplying highest quality boron compounds for more than fifty years. One single organization—from mine to refined product—assures top grade.
PACIFIC COAST BORAX CO.
DIVISION OF BORAX CONSOLIDATED, LIMITED
ANHYDROUS BORAX
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BORAX—BORIC ACID
MANUFACTURERS OF FAMOUS "20 MULE TEAM" PACKAGE PRODUCTS
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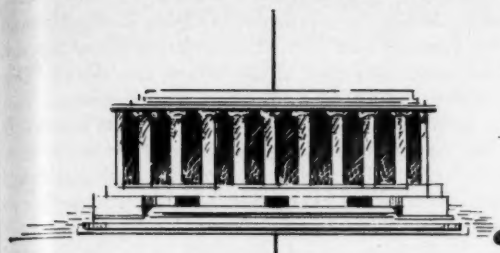
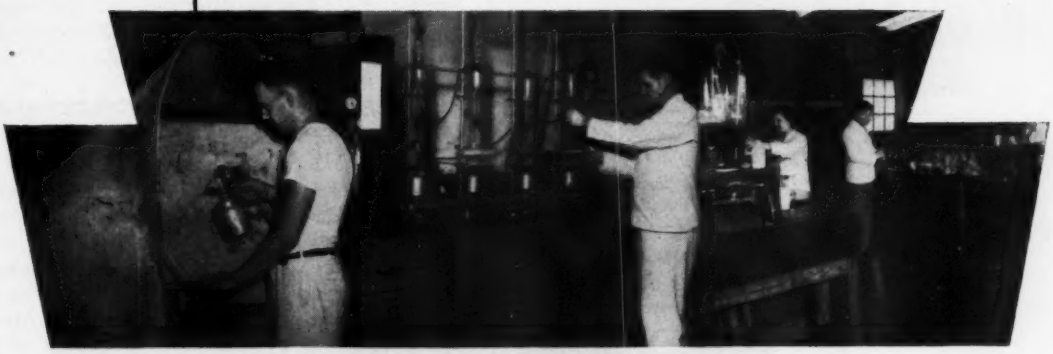


here's the big reason
Hommel will have it first!



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144 Years of Ceramic Experience

CERAMIC PROGRESS . . . . . THE RESULT OF CONTINUOUS RESEARCH

Since 1891, research at the O. Hommel Company has been an important factor in the development of OHCO Ceramic Supplies. The present research work carried on by the O. Hommel Company Fellowship in Ceramics at Mellon Institute since 1934 represents the best in research.

At the same time a program of continuous and intensive research and development work is going on in the modern plant and laboratories in Carnegie, Pa. and in the new West Coast Laboratory at Los Angeles.

We are keenly aware that only through research can we produce the finest and most efficient ceramic materials and supplies. We are justifiably proud of our many contributions to the ceramic industry through research . . . among them have been a number of "CERAMIC FIRSTS."

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West Coast Office, 4747 E. 49th St., Los Angeles, California.

World's Most Complete Ceramic Supplier

Pennsalt

Aqueous Hydrofluoric Acid

For polishing and etching glass

Available in 60% and 70% commercial grades

Packed in 165, 450 and 900 pound steel drums

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Pennsalt Chemicals

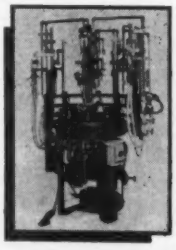
Kahle

when *production* COUNTS!

MACHINE-PRODUCED 3-PILLAR HARD GLASS STEMS ... ANOTHER KAHLE SOLUTION TO DIFFICULT PROBLEMS OF ELECTRONIC TUBE PRODUCTION.

Hand-blown hard glass stems proved too costly for a recent Kahle client. The problem was to find a machine capable of mass-producing uniform 3-pillar hard glass stems. Kahle's solution was to design and build the special purpose machine, Model 1958, shown below. This unique, hydrogen-fired machine permits semi-skilled operators to produce the hard glass stems in quantity ... maintaining rigid quality control.

This is but one of hundreds of problems solved by Kahle. In every case, Kahle's experience and ability have resulted in the design, development and production of a machine engineered to produce results as specified. Working closely with your organization, Kahle's experienced staff of electronic and equipment engineers will, at your request, recommend a solution to your own specialized production problems. Learn how Kahle's more than 40 years of practical experience can benefit you ... write Kahle now.



Kahle ENGINEERING COMPANY
1314 SEVENTH ST. NORTH BERGEN, N. J.

PENNSALT MAKES APPOINTMENT

James M. McWhirter, formerly Southern Works Manager for the Pennsylvania Salt Manufacturing Company, has been appointed Manager of the Wyandotte Works, it has been announced by W. F. Mitchell, Vice President.

Mr. McWhirter replaces G. A. Nelson, who, because of his wide background and experience in electrochemical engineering, is being assigned to general engineering and consultative work in connection with the compay's current expansion and plans for future developments.

Mr. McWhirter joined Pennsalt from the General Chemical Company in 1945. He was assigned to the Natrona, Pa., plant and later became Superintendent. He has also served at the Calvert City, Kentucky, Montgomery, Alabama, and Bryan, Texas plants.

KAISER ALUMINUM APPOINTMENTS

Appointment of Russel T. Drennan and Joseph A. Voss, Jr., as Sales Managers in eastern districts of the Chemical Division of Kaiser Aluminum & Chemical Sales, Inc., has been announced by F. M. Cashin, General Sales Manager.

Mr. Drennan will have supervision over sales and development of the Division's complete line of basic refractory brick, mixes and mortars along the Atlantic seaboard. A graduate of McKendree College of Lebanon, Illinois, Mr. Drennan was with the Aluminum Company of America and at Kaiser Aluminum's Baton Rouge, La., plant prior to joining the chemical sales organization.

Mr. Voss will be in charge of Midwest sales, including the steel centers of Pittsburgh, Cleveland, Detroit and Chicago.

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FRANK F. FERGUSON, NOTED GLASSMAN, DIES

Frank F. Ferguson, 83, former Illinois Glass Company executive and prominent figure in the glass industry, died on September 13 in his home at Alton, Illinois.

A native of Alton, Mr. Ferguson joined the Illinois Glass Company and eventually became Sales Manager and Secretary of the company. With the merger of the Illinois Glass and Owens Bottle companies in 1929, Mr. Ferguson retired.

Mr. Ferguson was a founder and one of the first presidents of the Glass Container Association of the United States and Canada.

He is survived by his sister, Mrs. Beatrice Sparks, and a nephew, Warren Sparks, manager of the Owens-Illinois Glass Container Division branch office at Kansas City.

DIAMOND ALKALI FORMS TWO NEW SUBSIDIARIES

Diamond Alkali Company has announced the formation of two new subsidiary companies to handle its rapidly-increasing volume of export sales.

The new concerns, both incorporated in Delaware, began their activities on September 1. Diamond Alkali Inter-American Corporation will be the sales outlet for Diamond chemicals in Latin America and other countries in the Western Hemisphere outside of the United States; and Diamond Alkali International, Inc., will serve all other areas of the world.

Offices and facilities of both new companies will be at 122 East 42nd Street, New York City. S. S. Savage has been elected President of the new export companies.

Fe

Low iron content is one of the outstanding qualities of Gold Bond glasshouse lime and limestone products. Only National Gypsum can supply *all* of these products—Gold Bond High Calcium and Dolomitic Limestone, Gold Bond Dolomite Fluxing Lime and Hydrates, Gold Bond Low-Iron Calcium Carbonate, also pottery and casting plasters.

Gold Bond INDUSTRIAL PRODUCTS

Ceramics Division

NATIONAL GYPSUM COMPANY
BUFFALO 2, NEW YORK

Nature's Gift to Industry

Powdered Silica of the highest Quality results from grinding these pure Ottawa and Rockwood sands.

• The Silica Sands of Ottawa and Rockwood, purified by nature's processing over untold ages . . . mined, cleansed and graded by special refining at our plants, offers glass-makers Silica Sands of supreme quality.

A battery of special electric ovens for annealing of light ware for the electronics division of a prominent manufacturer. These ovens are now employed in three plants.

Whatever your problem in the Glass Industry—our organization can design, engineer and construct the equipment and plants to meet your every requirement.

Superior equipment is our practice — Service is our creed.

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Design, Erection and Operation of Manufacturing Plants and Furnaces for All Types of GLASS WARE

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CHAMBER OF COMMERCE BUILDING, PITTSBURGH 19, PA.

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Glass Forming, Decorating and
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- Tandem Block Combustion Units
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Detailed information gladly sent upon request

NATIONAL AIROIL BURNER CO., INC.
1255 East Sedgley Avenue, Philadelphia 34, Pa.

EDWIN M. RUPP, A.C.S. TREASURER, DIES

Edwin M. Rupp, Treasurer of the American Ceramic Society in 1951 and 1952, died at Lake Wales, Florida, at the age of 53.

Mr. Rupp was a former representative in the Columbus area of United Feldspar & Mineral Corporation and National Engineering Company. At the time of his death, he was Vice President and Treasurer of the Flamingo Tile Company at Lake Wales, Florida. He has also been associated with Cambridge Tile Company, Square Deal Company, Yancey Cyanite Company, Clinchfield Sand & Feldspar Corporation, National Fireproofing Company, U. S. Bureau of Mines and the Surface Combustion Corporation.

Mr. Rupp, born October 8, 1898 in Middletown, Ohio, attended grade school and high school. He was enrolled in Chemical Engineering at Purdue University and received a B.Sc. degree in Ceramic Engineering from Ohio State University in 1921.

A member of the American Ceramic Society since 1923, Mr. Rupp has held the positions of Chairman and Trustee of the Materials and Equipment Division. He was elected a Fellow in 1947 and was also a member of the Institute of Ceramic Engineers.

He is survived by his wife, Elizabeth, and two sons, Robert at Lake Wales, and Richard with the U. S. Army in Germany, and a daughter, Margaret.

NEW GREENHOUSE CONSTRUCTION

A new design in greenhouse construction, employing insulating glass for solar heat with electricity for control and additional heat, less costly for production of healthier and vigorous plants, was described recently by M. O. Whithed, rural supervisor of the Atlantic City Electric Company, speaking at the North Atlantic section meeting of the American Society of Agricultural Engineers at the University of Maine.

The new type greenhouse was put into operation in November 1951 at the Seaview Country Club, Absecon, New Jersey, and was used primarily for production of all kinds of flowers for the club and for starting many varieties of perennial plants for the summer gardens.

The greenhouse measures 31½ feet long and 15 feet wide, and is built of cement block and steel, with sides of Thermopane insulating glass in units 18 by 42 inches. Seven-eighths of the roof is also of the insulating glass.

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Automatic Glass Machinery
For the Manufacture
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BULB BLOWING MACHINES—AMPULE MACHINES
FORMS ALL TYPES AND SHAPES OF BULBS MADE FROM GLASS TUBING
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TORCHES—BURNERS
DIFFERENT TYPES AND SHAPES MADE ON EISLER'S AUTOMATIC AMPULE MAKING MACHINES
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Need for production: Simpson Mixer, Raymond Mill, one or two Vibrating Screens. Please give full particulars. P. O. Box 1351, Church Street Station, New York 8, New York.

HELP WANTED

WORKS DIRECTOR — GLASS FACTORY

Executive Works Director in Ohio pressed glass handplant. Not large but very substantial fifty-year-old enterprise. Administrative abilities and practical general knowledge of factory operations required. Responsible for purchasing and general office. Report directly to President. Competent assistance by Works Manager, Chemist and Industrial Engineers. Lifetime position and commensurate income, including profit sharing, for right party. Present occupant retiring. Application will be treated absolutely confidential if desired. Write in full detail to Box 124, c/o The Glass Industry, 55 W. 42nd St., New York 36, N. Y.

SITUATION WANTED

GRADUATE ENGINEER with eleven years experience in glass plant operation, construction and maintenance desires position as plant engineer, superintendent or assistant. Reply Box 122, c/o The Glass Industry, 55 W. 42nd St., New York 36, N. Y.

GLASS TECHNOLOGIST. Hon. grad. chem., ceramic and furnace eng. Extensive experience in Research-Development and Production. Desires to change position. References, credentials, production records available. Senior position. Reply Box 125, c/o The Glass Industry, 55 W. 42nd St., New York 36, N. Y.

BUSINESS OPPORTUNITIES

NEUTRAL GLASS. Continental firm, working tubes and vials, intends selling all information about neutral glass for serum and transfusion bottles. Glass conforms with U.S.P. Also selling some semi-automatic machines. Reply Box 123, c/o The Glass Industry, 55 W. 42nd St., New York 36, N. Y.

GUSTIN-BACON NAMES NEW YORK MANAGER

Gustin-Bacon Manufacturing Company has announced the appointment of Edward A. McCabe as Manager of its New York division. Mr. McCabe, who lives in Yonkers, New York, will be in charge of all glass fiber insulation, industrial and railroad division sales in New England, New York, New Jersey, Pennsylvania and Delaware.

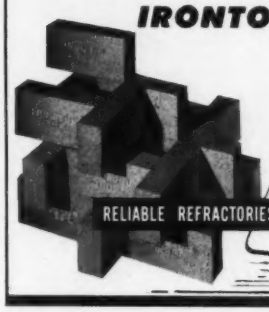
ANNUAL REPORT MERIT AWARDS ANNOUNCED

From the 5,000 corporation annual reports for 1951 rated in the Twelfth Annual Survey, ten glass (except glass containers) companies are being cited with "Merit Award" certificates by Weston Smith, Director of the Annual Report Survey for *Financial World*, which will celebrate its Golden Anniversary for fifty years of service in October.

The companies singled out for certificates are American Window Glass Company, Anchor Hocking Glass Corp., Bausch & Lomb Optical Company, Corning Glass Works, Glass Fibers, Inc., Libbey-Owens-Ford Glass Company, Mississippi Glass Company, Owens-Corning Fiberglas Corp., Pittsburgh Plate Glass Company and Univis Lens Company.

For extra service under severe operating conditions, specify

IRONTON STEEL FIRE BRICK laid up with IRONTON ALSET High bond strength mortar



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